Appendix L
Snohomish County
Smith Island Estuary Restoration
Interior Drainage Report
Preliminary 60 Percent Design

November 2013

Submitted to:
Snohomish County
3000 Rockefeller Avenue
Everett, WA 98201

Prepared by:
Greg Laird, Principal Engineer
Otak, Inc.
10230 NE Points Dr., Suite 400
Kirkland, WA 98033
425-822-4446

Acknowledgements

Smith Island Estuary Restoration
Interior Drainage Report
Preliminary 60 Percent Design

Submitted to:

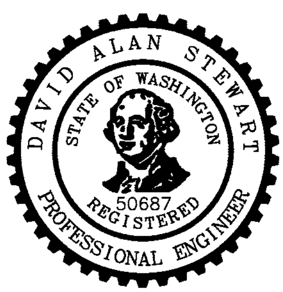
Snohomish County
Department of Public Works
3000 Rockefeller Avenue, M/S 607
Everett, Washington 98201

Prepared by:
Otak, Inc.

Dave Stewart, PE
Project Engineer

Chris Ewing, EIT
Engineering Designer

Neil Schaner, EIT
Engineering Designer



Approved by:
Greg Laird, PE____
Principal

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Executive Summary

The hydrologic and hydraulic analysis described herein evaluates design alternatives for a drainage system for the area interior to the Smith Island Estuary Restoration project setback dike in Snohomish County, Washington. The Smith Island Estuary Restoration project includes the construction of a setback dike, and breaching of an existing dike along Union Slough, which is a tributary to the Snohomish River and is tidally influenced by Puget Sound. The interior area of Smith Island is at a relatively low elevation and exhibits relatively high groundwater levels through much of the year due to inflow from the adjacent Union Slough, the nearby Snohomish River, rainfall, as well as coastal waters. The land use of much of the island is currently fallow pasture with areas of freshwater wetlands, and areas interior to the proposed setback dike alignment are used for agriculture.

The alignment of the setback dike is within Snohomish County property, and the interior land uses include a tree nursery business located on the opposite side of a remnant tidal channel from the setback dike. The tree nursery's drain tiles outlet to the tidal channel, and high surface water in the channel can interfere with adequate drainage of the nursery property. Drainage improvements will be constructed as a part of the Smith Island Estuary Restoration project to manage the stormwater runoff from the interior area of the setback dike so that property owners are not adversely impacted. The proposed drainage improvements include a drainage pond and culvert to drain the existing tidal channel (West Tidal Channel) and maintain low water surface elevations to avoid impacting the nursery operation. The drainage pond will outlet to Union Slough, but it can only drain when the water levels in the slough are lower than the level in the pond without the addition of a pump station.

The soils, land uses, and existing flow patterns of the area were identified for the area interior to the dike, and were used to develop the simulation of the hydrologic response under the proposed conditions of a setback dike and drainage system. The drainage system consists of a drainage pond that will drain the tidal channel next to the tree nursery property, with several design alternatives evaluated for the pond outlet. The following alternatives are considered for draining the pond: 1) one gravity outlet, 2) two gravity outlets, 3) a pump station with a total outflow of two cubic feet per second (cfs) and two gravity outlets, or 4) a pump station with a total outflow of four cfs (presumably two 2-cfs pumps) and two gravity outlets. The drainage analysis for the study area includes conservative assumptions in the simulation of stages for Union Slough based on Snohomish River data, seepage rates into the system from nearby groundwater sources (determined by Shannon and Wilson, October 2013, Appendix F), and surface runoff from saturated soil conditions to determine surface water levels within the tidal channel and drainage pond for the approximately 60-year period of record of rainfall data.

The results from the drainage analysis indicate that the use of two gravity outlets for the pond significantly reduces water elevations during the simulation, but the stage on Union Slough restricts gravity drainage to low stage windows. The limited duration of the low tide and river stage window does not allow a gravity drainage system to reliably maintain surface water levels lower than the relatively low tile drain inverts based on seepage inflow from nearby subsurface sources and rainfall on periodically-inundated soils. The time periods when drainage of the pond is critical tends to coincide with higher stages on Union Slough, when gravity drainage will not occur.

The water surface elevations in the tidal channel can be managed by regulating the elevations in the drainage pond because a culvert connects the channel to the pond. When a pump system with a total output of two cfs is operated as a contingency measure, the simulation indicates that when the pump station is set to turn on when water surface elevations are near the tile drain inverts, the two cfs flow rate provides the capacity necessary to maintain surface water below the tile drains for most conditions, but not the largest flood events. The addition of a second two-cfs pump to produce a four-cfs capacity pump system drains the drainage pond system faster and maintains a lower peak water surface elevation in the channel during the large flood events. The additional two-cfs pump does not provide significant benefit for the more frequent conditions and operation.

Section 1—Introduction

This report presents the results of the hydrologic and hydraulic modeling for the area interior to the proposed Smith Island Estuary Restoration Project setback dike in Snohomish County, Washington. The purpose of this effort is to determine the surface runoff conditions of the area interior to the proposed setback dike (the study area) in order to design the interior drainage facilities to serve the property owners located landward of the proposed setback dike.

An initial interior drainage modeling study conducted by TetraTech (May 2013A) to support the Smith Island Restoration Project Environmental Impact Statement (EIS) was reviewed and the hydrologic and hydraulic modeling described herein was developed based on updated design features of the Smith Island setback dike. Additionally, Shannon & Wilson and Snohomish County evaluated groundwater and seepage conditions and their impact on the dike design and interior drainage (Shannon and Wilson, October 2013, Appendix F) and these results are included in this modeling study. All elevation data were collected relative to North American Vertical Datum 1988 (NAVD88).

Project Description

Smith Island is located in Snohomish County, Washington, adjacent to the City of Everett, on the west side of Union Slough and east of the Snohomish River within Sections 9 and 10 of Township 29 and Range 5 (Figure 1). The objective of the Snohomish County Smith Island Estuary Restoration Project is to restore critical habitat for salmonids and other native aquatic species in the Snohomish River basin by constructing a setback dike and breaching an existing dike to restore tidal influence to approximately 340 acres of the Snohomish River estuary.

The proposed setback dike will extend from the existing dike along Union Slough, through the former agriculture land between the East and West Tidal Channels, across 12th Street NE, and connect to the dike on the north side of the City of Everett's Water Pollution Control Facility (Figure 1). The proposed setback dike will be built to an elevation of 15 feet (NAVD88). The existing dike along Union Slough ranges in top elevation from approximately 12 to 14 feet from the connection with the setback dike to Interstate 5 (I-5). The elevation of the dike around the City of Everett's Water Pollution Control Facility (WPCF) is 15 feet (NAVD88). The elevation of the proposed setback dike provides more than two feet of freeboard above the 10-year flood elevation. The elevation of 15 feet is the 100-year base flood elevation for this area.

The Smith Island Estuary Restoration project area includes the dike footprint and access roads, County-owned property on the interior area (west side) of the dike, as well as the restoration area on the east side of the dike. The study area for the hydrologic and hydraulic analyses described herein consists of County and privately-owned property on the interior area (west side of the dike) that will drain to the drainage conveyance system under the proposed project conditions. The hydrologic and hydraulic study area extends from Union Slough at the north end to 12th Street NE at the south end, and from the setback dike at the east end to I-5 on the west end. The project area south of

12th Street NE is not included in this study because it is within the City of Everett and they will evaluate their requirements for interior drainage on their property.

The study area currently drains to Union Slough through the East and West Tidal Channels, and to the Snohomish River through the Southwest Tidal Channel. In previous reports by others, the East, West, and Southwest Tidal Channels have been referred to as Tidal Channels A, B, and C, respectively.

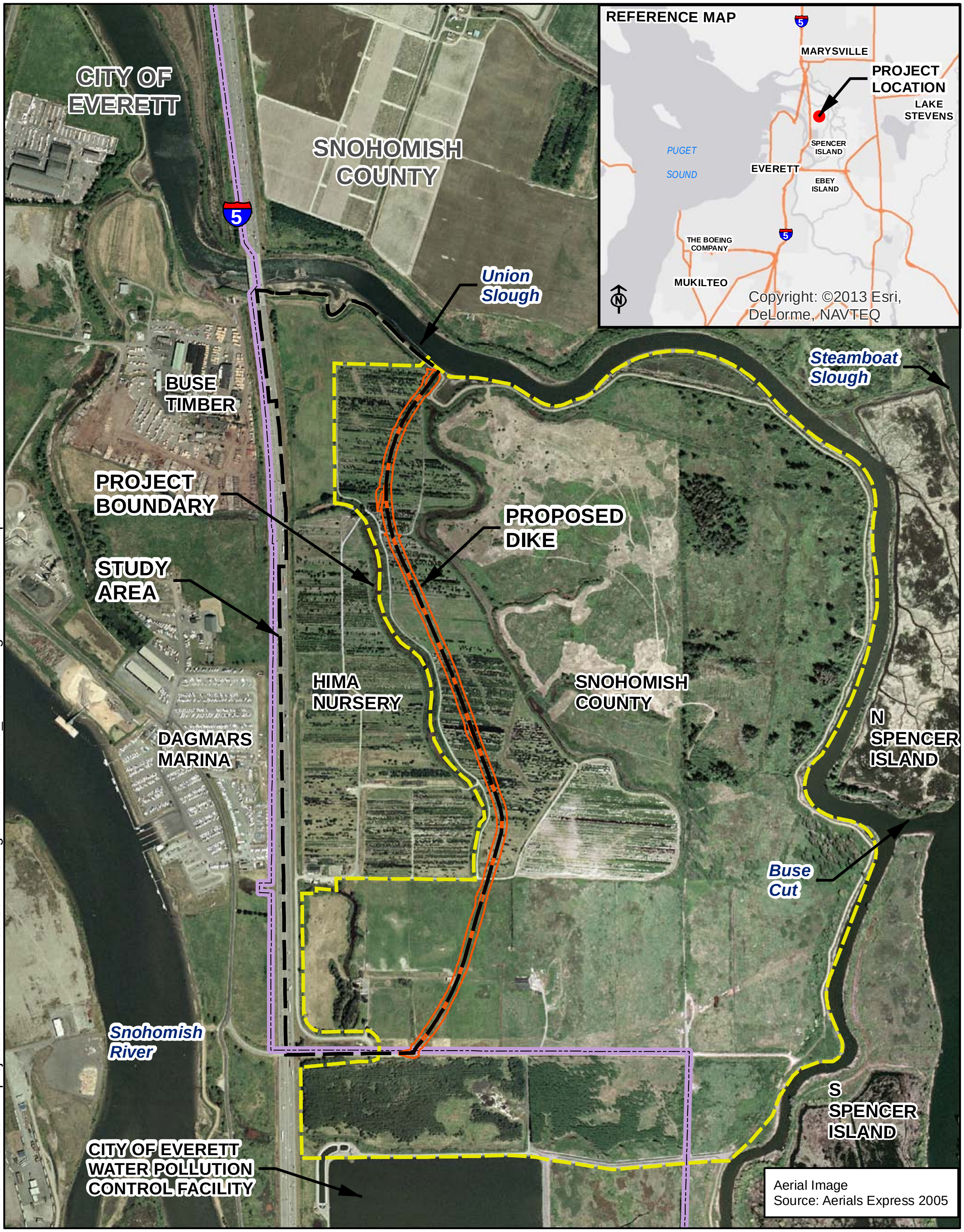

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Figure 1:
Location Map

Smith Island Estuary Restoration

Legend
- Smith Island Project Boundary
- Study Area
- Everett City Limits

Snohomish County

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Date: 10/3/2013

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Section 2—Existing Drainage Conditions

Land Use

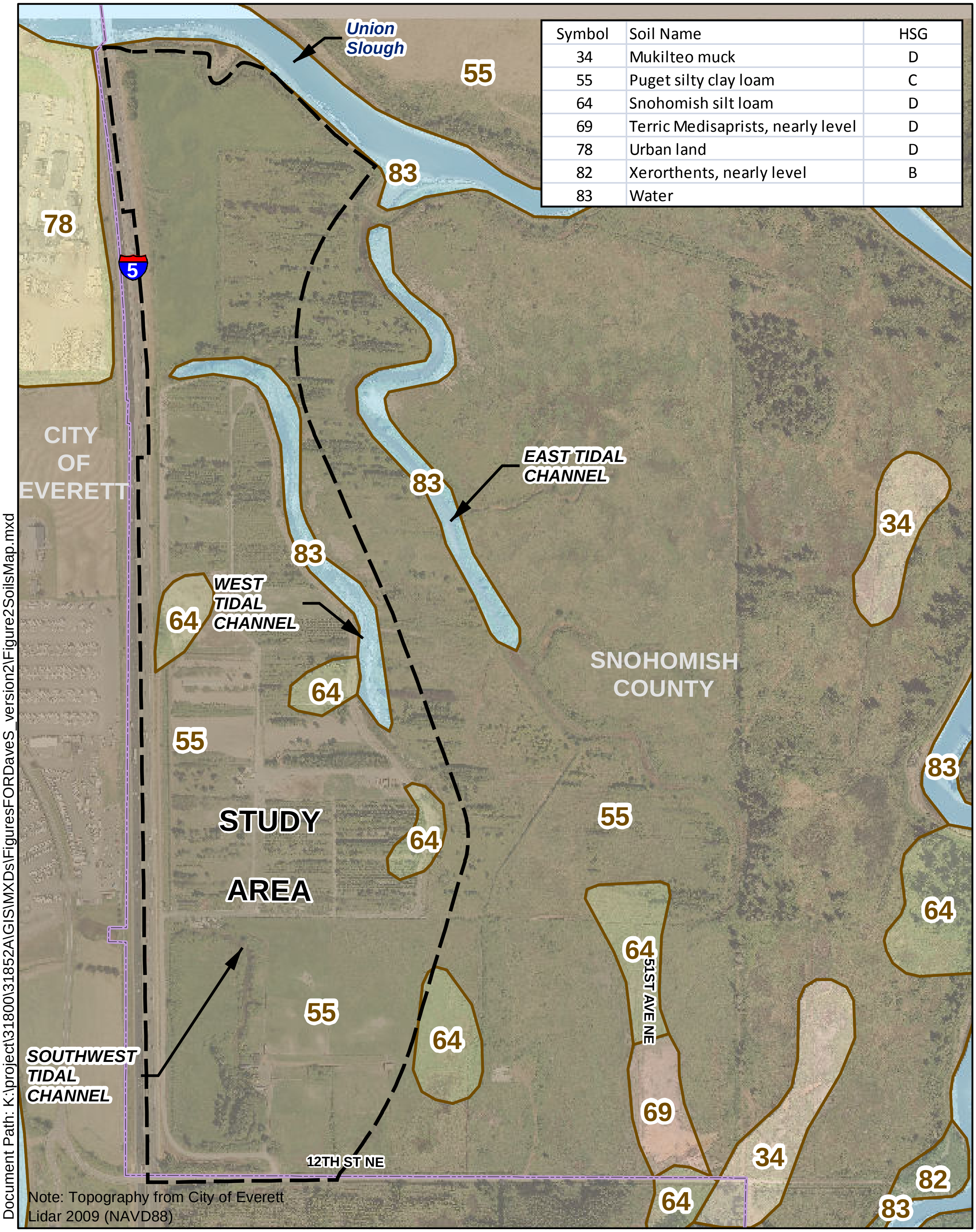
The land use of the 130-acre study area is primarily agricultural in nature. Most of the study area has been a tree nursery for the past 10 years or more. Currently Hima Farms operates a tree nursery on approximately 70 acres in the northern portion of the study area. There is a portion between the Hima Farms operation and Union Slough that has been pasture grass for more than 10 years. The southern third of the study area is mostly pasture for horses under the care of Snohomish County. There is a caretaker's house, and several barns and sheds that serve the horse farm. There are trailers and various temporary facilities that serve Hima Farm's tree nursery operation. Gravel and dirt roads cross the study area. One gravel road serves as a frontage road to I-5, while another gravel road divides the tree farm operation from the horse farm. The tree farm has other gravel roads to serve its operations. Dirt roads provide access to the various pastures on the horse farm. The remnant tidal channels, and open ditches, such as those along the toe of the existing dike, are classified as open water and have saturated conditions throughout the year.

The 12th Street NE public access road is aligned in an east-west direction at the southern border of the study area and the border between Snohomish County and the City of Everett jurisdictions. The Puget Sound Energy (PSE) underground natural gas pipeline crosses the southern portion of the study area approximately 75 feet north of 12th Street NE. The area south of 12th Street NE is owned by the City of Everett and includes the Everett Water Pollution Control Facility. The project area south of 12th Street NE is not included in this study because it is within the City of Everett and they will evaluate their requirements for interior drainage on their property.

Soil Types

The study area consists primarily of silty clay loam that has been formed by floodplain alluvium material, and is high-quality farmland when drained. The USDA Natural Resource Conservation Service (NRCS) has mapped the soils of the study area as generally Puget silty clay loam or Snohomish silt loam soil types (Figure 2). It is assumed that the soil types have been modified by soil amendments and agricultural practices within the tree nursery property. The areas of the project site south of the Hima Nursery and north of the 12th Street NE alignment consist of Category II Freshwater Wetlands, and are inundated with surface water in depressions during winter months based on site reconnaissance.

The project geotechnical report found that estuarine deposits were the primary near-surface soil type on the site (Shannon and Wilson, October 2013). The estuarine soils are described as "soft, organic silt and clayey silt with abundant organics and scattered peat layers" to a depth of about four to eight feet. Alluvial deposits were discovered in some borings underlying the estuarine deposits and are described as "very loose to dense, trace of silt to silty sand." According to the National Resources Conservation Service (NRCS), these soils can generally be classified as belonging to hydrologic soil group (HSG) C.



Symbol	Soil Name	HSG
34	Mukilteo muck	D
55	Puget silty clay loam	C
64	Snohomish silt loam	D
69	Terric Medisaprists, nearly level	D
78	Urban land	D
82	Xerorthents, nearly level	B
83	Water	

Figure 2:
Soils Map

Smith Island Estuary Restoration

Legend
Study Area
Soil Boundary
Everett City Limits

Snohomish County

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Date: 10/2/2013

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Drainage Features

The West Tidal Channel (Photos 1 and 2) has been separated into two sections by a field crossing near the northeastern corner of the Hima Farms tree nursery property, and the nursery operation pumps water from the southern portion of the West Tidal Channel over the earthen field crossing to the north portion of the channel to maintain water surface elevations below the drainage tile inverts (Photo 3), which were surveyed by Snohomish County (Appendix A). Surface water in the West Tidal Channel north of the earthen field crossing is connected to a 48-inch CMP under I-5. As of August 2013, the 48-inch CMP culvert is partially obstructed by accumulated sediment and debris.

Photo 1.
The West Tidal Channel looking South from approximately Station 33+00 of the proposed setback dike in February 2013.

An east-west ditch is connected by 12-inch diameter pipes and a gate valve to the West Tidal Channel and the East Tidal Channel (Appendix B). The 12-inch pipe from the West Tidal Channel into the ditch has an invert elevation of -1.43 feet on the west end, and -1.24 feet on the east side based on field survey. The ditch contains ponded water through much of the year.

Photo 2.
The northern end of the West Tidal Channel looking northwest from the earthen field crossing at approximately Station 55+00 of the proposed setback dike in February 2013.

Interstate-5 Roadway Drainage

The drainage of I-5, the western boundary of the study area, was determined by a review of Washington Department of Transportation as-built drawings (WSDOT, 1990), Light Detection and Ranging (LiDAR) topographic data, and field reconnaissance (June 2013). I-5 roadway corridor is crowned along most of the study area such that the northbound lanes drain eastward into the study area and the southbound lanes drain to the west. The I-5 roadway is superelevated to the west through a slight curve approximately 1,600 feet south of the bridge over Union Slough. Within this superelevated portion of I-5, a 1,200-foot section of the northbound lanes drain westward into a series of catch basins located in the median. These catch basins all drain to the west side of I-5 per the 1990 WSDOT as-built drawings.

Existing Conditions Sub-basin Delineation

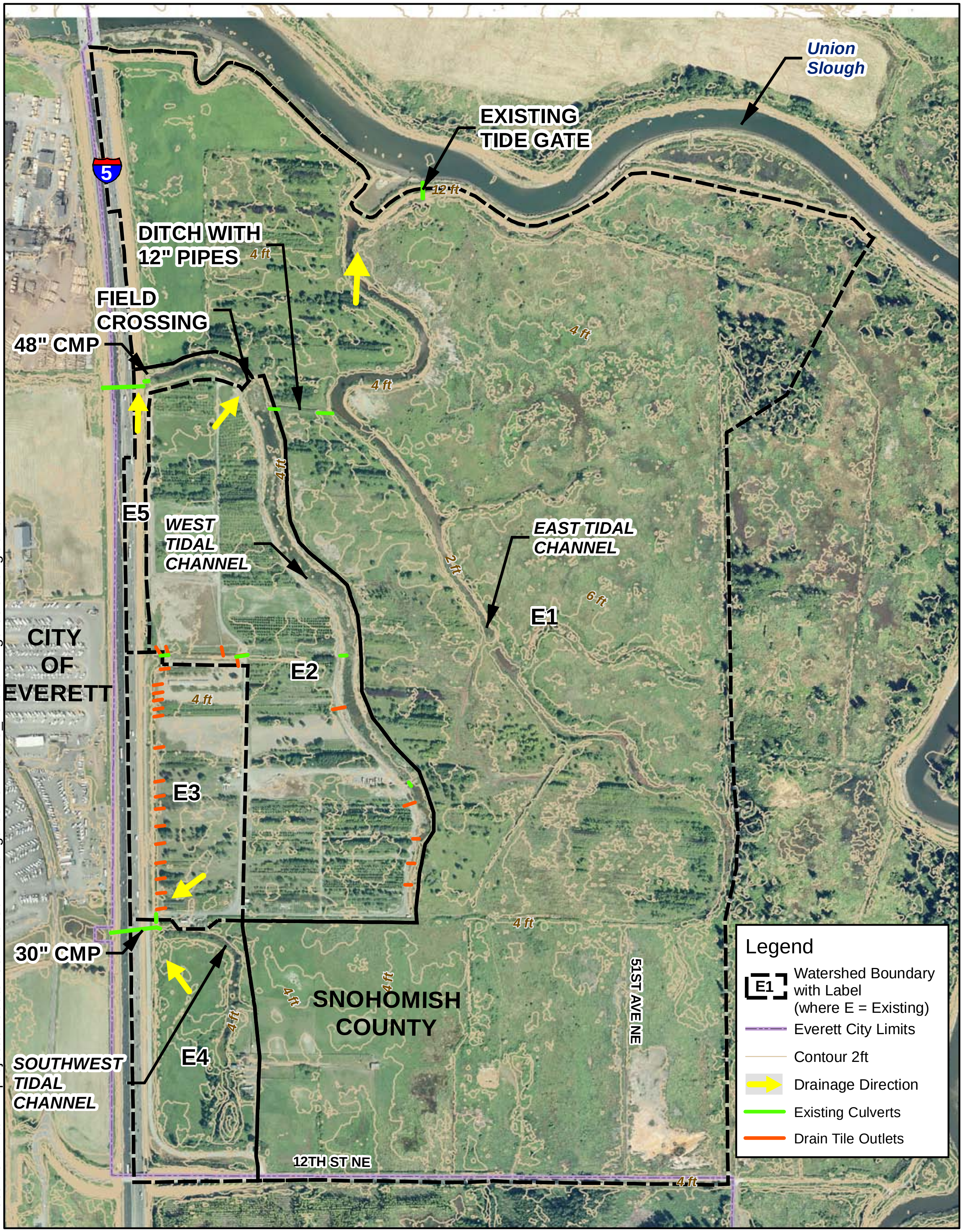
Five sub-basins were delineated within the study area for the existing conditions (Figure 3). The sub-basin boundaries were determined by an analysis of surface topography and the drainage direction of ditches, culverts, and drain tile pipes located throughout the site and field verified by site reconnaissance during spring and summer of 2013. Surface topography was established by Snohomish County LiDAR elevation data and topographic surveys by Snohomish County throughout the study area. The elevation and location of ditches, culverts, and drain tile pipe inverts were also established by surveys conducted by Snohomish County.

Photo 3.
One of the drain tiles conveying irrigation and runoff water from the tree nursery operation to the West Tidal Channel in February 2013.

Sub-basin E1

Sub-basin E1 consists of a significant portion of the Snohomish County-owned property within the study area and the restoration area east of the dike, which drains to the East Tidal Channel under existing conditions. The sub-basin E-1 drainage area consists primarily of undeveloped, fallow pasture, open space, and water features such as the tidal channels and remnant agricultural ditches. In addition, a short segment of I-5 near Union Slough drains into sub-basin E1 in the current condition. The existing grade typically ranges between four to five feet elevation within the sub-basin, except for the tidal channel and ditch bottoms which have elevations as low as approximately -3.0 feet at some locations. The ditches typically contain ponded water throughout the year, and do not necessarily drain to the East Tidal Channel during portions of the year due to the relatively flat topography. The boundaries for sub-basin E1 were delineated based on surface topography and identification of ditches that are likely to drain to the East Tidal Channel. Also, a portion of the area in sub-basin E1 south of the tree nursery property may drain to the Southwest Tidal Channel; however, the area is assumed to drain to the east as a conservative assumption so that it is routed into the proposed drainage system for design calculations under the proposed conditions.

The sub-basin E1 drainage area is modified under the proposed conditions by the setback dike alignment, which partitions the drainage area west of the dike to flow into the drainage conveyance system and out to Union Slough, and the remaining area east of the setback dike alignment will continue to flow to the East Tidal Channel.



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Date: 10/2/2013

Figure 3:
Existing Conditions Sub-basin Map

Snohomish County

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Smith Island Estuary Restoration

Note: Topography from City of Everett Lidar 2009 (NAVD88)

Sub-basin E2

Sub-basin E2 includes areas of the tree nursery property, and is bounded by the east bank of the West Tidal Channel at the sub-basin's eastern edge, and a surface drainage divide along the tree nursery property line to the south. The western and northern boundaries of sub-basin E2 have been defined by the extent of subsurface drain tiles located throughout the property. The location and orientation of the drain tile pipes have been determined based on field reconnaissance, survey (Appendix A), personal communication (A-1 Landscaping, September 2013), as well as drawings from the Snohomish Conservation District (March 2011). In the northern portion of the tree nursery property, drain tile pipes run north-south and drain to a ditch in the center of the tree nursery property. The ditch connects to the West Tidal Channel through an 18-inch polyvinyl chloride (PVC) pipe to the east and connects to a ditch along the western edge of the tree nursery property by a 24-inch pipe with a manually-operated gate. In the southern portion of the tree nursery property, drain tile pipes run east-west and discharge to both the east and west sides of the tree nursery property. On the east side, the drain tile pipes discharge directly into the West Tidal Channel.

Sub-basin E3

Sub-basin E3 is the southwestern area of the tree nursery property. It is bounded by the crown of I-5 to the west, and the extents of drain tiles to the south, east, and north. Runoff flows to a ditch along the west property line of the tree nursery. A 24-inch CMP with a flap gate and invert elevation of 0.61 feet allows gravity drainage from the western ditch into the Southwest Tidal Channel; however, this elevation is above the drain tile inverts of the tree nursery (the lowest tile drain invert is -0.60 feet, Appendix A). A pump station is operated under existing conditions to move stormwater from the western ditch to the south into the Southwest Tidal Channel to maintain low water surface elevations within the ditch.

Sub-basin E4

Sub-basin E4 is the County-owned property that drains to the Southwest Tidal Channel which drains under I-5 through a 30-inch culvert with an invert elevation of 0.48 feet. The drainage area is bounded by the crown of I-5 to the west, the crown of 12th Street NE to the south, and surface drainage divides to the north and east of the Southwest Tidal Channel. Portions of the sub-basin E1 area may drain into the Southwest Tidal Channel, but have been assumed to drain east as a conservative assumption for designing the drainage system for the proposed conditions.

Sub-basin E5

Sub-basin E5 is the area draining to the ditch along I-5 and the northern section of the West Tidal Channel that is disconnected from the southern section of the West Tidal Channel by an earthen field crossing. Sub-basin E5 is bounded by the crown of I-5 to the west, an access road into the tree nursery to the south, the field crossing and surface divides to the east and north. The disconnected section of the West Tidal Channel drains west into the ditch through a CMP with a rusted out bottom and a top elevation of -1.53 feet. The ditch at the toe of the I-5 embankment collects runoff from a segment of I-5 and the disconnected section of the West Tidal Channel and drains off-site under I-5 through a 48-inch CMP, which is partially clogged by sediment and debris as of August 2013. The maintenance of this culvert is not within Snohomish County jurisdiction.

Section 3—Proposed Drainage Conditions

Drainage Improvements

Drainage improvements will be constructed to manage the stormwater runoff from the study area so that property owners are not adversely impacted. The drainage improvements include:

- A 36-inch diameter pipe with tide gate to replace the existing culvert with tide gate that outfalls to Union Slough

- A drainage pond with approximately 38 acre-feet of live storage to compensate for the loss of storage currently provided by the East Tidal Channel

- A 36-inch diameter pipe to connect the West Tidal Channel to the drainage pond including a flap gate to prevent the backflow from the pond to the tidal channel

- A toe ditch to convey seepage from the setback dike to the drainage pond, with a pipe and flapgate preventing backflow from the pond into the ditch.

- A pump station to provide additional capability for Hima Farms to maintain low water levels in the West Tidal Channel adjacent to their nursery

- A 36-inch diameter pipe with tide gate to provide a secondary outlet from the West Tidal Channel

- A 36-inch diameter culvert that will connect the toe ditch along the existing dike (that remains as it is) to the drainage pond

Proposed Conditions Sub-basin Delineation

Eight sub-basins were delineated within the study area for the proposed conditions on the landward side of the setback dike (Figure 4). As described for the existing conditions delineation, sub-basin boundaries were determined by survey of surface topography, ditches, culverts, and drain tiles.

The location of the setback dike modifies the existing condition sub-basin E1 (Figure 3) so that areas interior to the dike drain to the drainage pond or the West Tidal Channel. The additional areas assuming to drain to the West Tidal Channel are shown in Figure 4 as proposed conditions sub-basins 3 and 5 (P3 and P5). Proposed sub-basins 1 and 2 (P1 and P2) drain to the drainage pond under proposed conditions, instead of the East Tidal Channel. The remaining proposed conditions sub-basins (P4, P6, P7, P8) remain unchanged from the existing conditions.

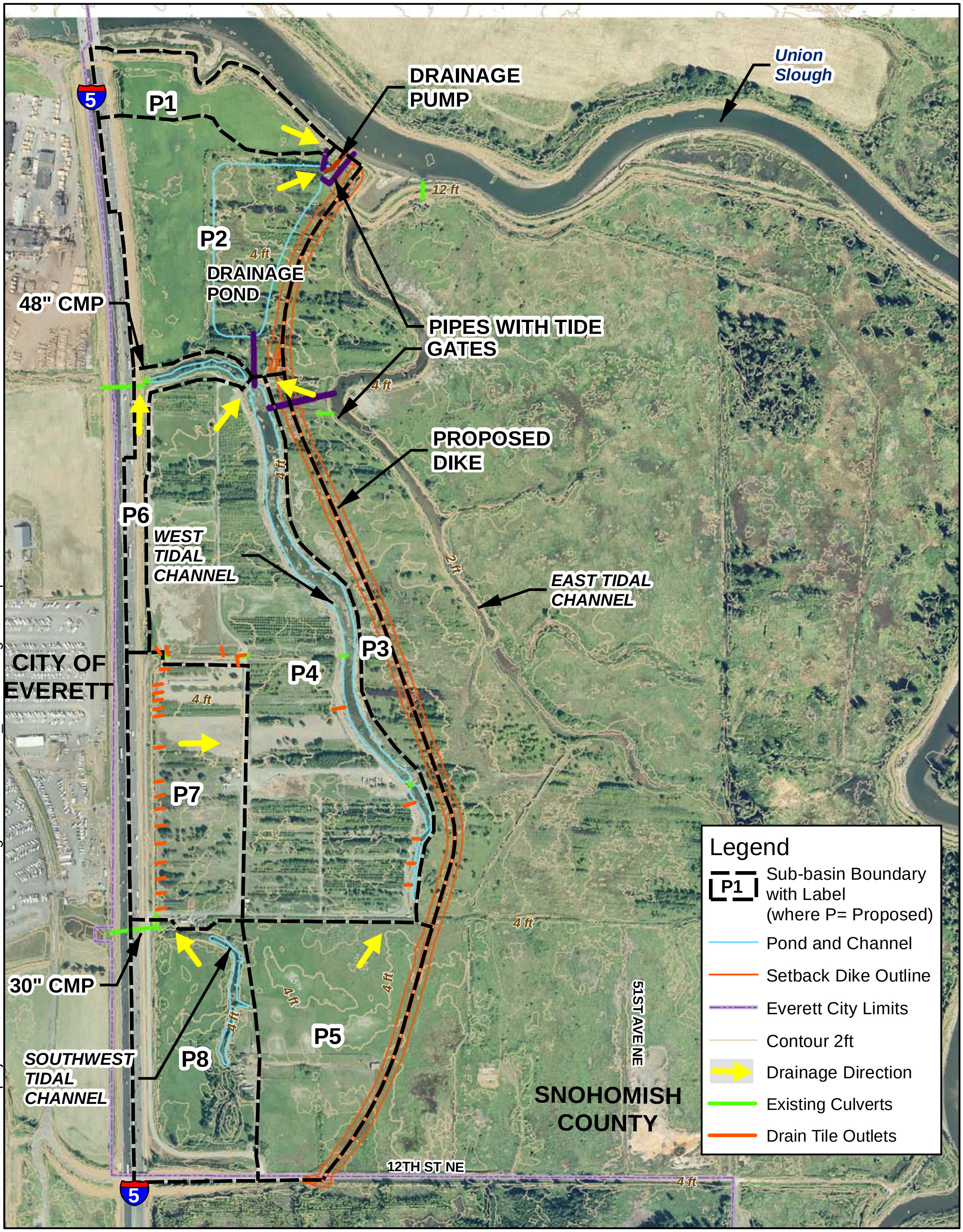

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Figure 4:
Proposed Conditions Sub-basin Map

Date: 12/2/2013

Snohomish County

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Note: Topography from City of Everett Lidar 2009 (NAVD88)

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Sub-basin P1

Sub-basin P1 is bounded by the top of the existing dike to the north and east, the crown of I-5 to the west, and a surface drainage divide to the south. Runoff is collected in an existing ditch located along the landward toe of the existing dike and is conveyed to the proposed pond through a proposed 36-inch Corrugated Polyethylene Pipe (CPEP) culvert.

Sub-basin P2

Sub-basin P2 is bounded by a surface drainage divide to the north, the top of the proposed setback dike to the east, a surface drainage divide along the West Tidal Channel to the south, and the crown and edge of I-5 to the west. I-5 is superelevated for approximately 1,200 feet at the western boundary near the 48-inch CMP culvert crossing. This portion of I-5 drains to catch basins located in the I-5 median which discharge to the west through storm drain pipes. North of the superelevated portion of I-5, 480 feet of northbound I-5 sheet flows east to the study area. Sub-basin P2 drains by surface flow to the drainage pond.

Sub-basin P3

Sub-basin P3 is bounded by the setback dike to the east and a surface drainage divide that runs along the West Tidal Channel to the west, and drains to the West Tidal Channel by surface flow. The toe ditch is located within sub-basin P3, but the toe ditch is assumed not to capture any surface flow from sub-basin P3 or seepage into the West Tidal Channel as a conservative assumption.

Photo 4.
Looking northwest into proposed conditions sub-basin area P5 in February 2013.

Sub-basin P4

Sub-basin P4 includes the majority of the tree nursery property, and the drainage boundaries and characteristics of sub-basin P4 will not be affected under proposed conditions and has the same extents as sub-basin E2.

Sub-basin P5

Sub-basin P5 is bounded by a surface drainage divide along the tree nursery property line to the north, the setback dike to the east, the crown of 12th Street NE to the south, and a surface drainage divide that runs along the east side of the Southwest Tidal Channel. This sub-basin is relatively flat with typical elevation ranging from four to five feet NAVD88 and surface depressions that do not drain during wetter months. The area shown as sub-basin P5 is assumed to drain to the West Tidal Channel and then to the proposed storage pond as a conservative measure, while some areas within sub-basin P5 may actually drain off-site to the Southwest Tidal Channel.

Areas of sub-basin P5 contain surface depressions and are classified as Category II Freshwater Wetlands (Photo 4). The storage volume of the surface depressions was calculated with CAD

(Autodesk Civil 3D 2012) (Appendix C) to determine elevations where stormwater will drain north to the West Tidal Channel.

Sub-basin P6

Sub-basin P6 represents the area that drains off-site to the west through a 48-inch CMP under I-5. The drainage area includes a portion of northbound I-5 and the disconnected northern section of the West Tidal Channel. The drainage boundaries and characteristics of sub-basin P6 will not be affected by the proposed project and has the same extents as existing conditions sub-basin E5.

Sub-basin P7

Sub-basin P7 includes the southwestern portion of the tree nursery property and a 1,300-foot section of northbound I-5. The drainage boundaries and characteristics of sub-basin P7 are not affected under the proposed condition and are the same as existing conditions sub-basin E3.

A pump station operated by the tree nursery moves stormwater from the west ditch to the Southwest Tidal Channel in the current condition. If the pump station were not operating and water surface elevation increases within the western ditch, stormwater may enter the drain tile inverts on the western property edge (the lowest tile drain invert is -0.6 feet in elevation) and drain towards the channel on the eastern property edge (the West Tidal Channel, with drain tile invert elevations varying from -1.71 feet up to 1.75 feet (Appendix A). As a conservation assumption, the sub-basin P7 surface runoff is assumed to drain to the West Tidal Channel to represent conditions where the pump station is not operating.

Sub-basin P8

Sub-basin P8 includes the southwestern portion of the project site and an approximately 1,350-foot section of northbound I-5. The drainage boundaries and characteristics of sub-basin P8 are not affected in the proposed condition and drains off-site in existing conditions as described for sub-basin E4.

Section 4—Drainage Analysis Methods

The interior drainage analysis used the Western Washington Hydrology Model (WWHM) 2012 for hydrologic simulation and the U.S. Environmental Protection Agency Storm Water Management Model (EPA SWMM) Version 5.0 to simulate the hydraulics of the proposed drainage system. The proposed conditions were modeled to evaluate design alternatives for the drainage system and determine the water surface elevations within the West Tidal Channel. The existing conditions were not modeled as a part of this study because the existing peak discharges do not affect design and the Tidal Channel water surface elevations vary in the existing condition based on the pumping rates by the tree nursery.

WWHM Hydrologic Model

The Washington State Department of Ecology Western Washington Hydrology Model 2012 (WWHM) was used to determine the stormwater flow rates from the study area into the drainage system. WWHM is a continuous simulation hydrologic modeling software that provides an interface for using the Hydrological Simulation Program Fortran (HSPF) model algorithms developed by the U.S. Geological Survey and U.S. Environmental Protection Agency.

WWHM Model Input

The proposed conditions were modeled in WWHM to simulate inflow rates into the drainage system from the study area.

WWHM requires input data for precipitation, evaporation, and land use, surface slope, and soil classification. Meteorological inputs such as precipitation and evaporation are included within WWHM and are chosen by selecting the project site from a map interface. For the study area, precipitation data from water years 1948 to 2009 is used from the National Weather Service Everett precipitation gauge with a scaling factor of 1.00 applied. Evaporation is applied as a universal Pan Evaporation Factor of 0.76, a standard value used for WWHM modeling.

The land cover of the area within the proposed setback dike primarily consists of farmland, fallow pasture, and a small number of gravel access roads and minor structures. There is relatively little elevation change across the study area with the exception of short steep slopes along the dike embankment (proposed and existing) and the I-5 corridor embankment.

Saturated soil conditions (hydrologic soil group D) were used in the hydrologic model during the length of the simulation as a conservative assumption rather than soil types classified as group C due to the relatively high groundwater levels, the proximity of the study area to tidally influenced waterways, and relatively low infiltration rates are expected. The use of saturated soil conditions in the model results in a higher volume of runoff per unit of rainfall.

The land cover of the study area was modeled in WWHM as primarily flat pasture with saturated soils. The steep areas along the dike and I-5 corridor were measured and included in the model as steep pasture with saturated soils. The proposed and existing gravel and paved roads are included as impervious areas. These include the access road on the landward side of the dike, the dike top access road, the proposed gravel parking lot, the gravel roads within and adjacent to the tree nursery property, and portions of the northbound I-5 roadway and 12th Street NE roadway. The water surface area of the proposed pond, the West Tidal Channel, and the Southwest Tidal Channel are assigned the "Pond" impervious land cover type in WWHM and directly contribute runoff to the hydrograph time series.

WWHM is utilized to create a runoff time series from the interior basins. Sub-basin surface and interflow runoff time series are output at a 15-minute time step from October 1, 1948 to September 30, 2009. Sub-basins were created in the model to represent the combined outflow from Sub-basins P1 and P2 to the proposed pond, the combined outflow from sub-basins P3, P4, P5, and P7 to the segment of the West Tidal Channel connected to the drainage pond. In addition, runoff was modeled for the individual sub-basins for determination of peak discharges.

One Percent Annual Chance (100-year) Runoff Analysis

The One Percent Annual Chance (100-year) rainfall depths for varying durations from NOAA (1973) and the USDA Soil Conservation Service (1964) were compared to observed rainfall depths from the December 1996 storm. The 24-hour 100-year storm and the 1996 event were modeled and the event with more conservative runoff volumes was used to evaluate a 100-year or larger storm in the SWMM model.

SWMM Hydraulic Model

The U.S. Environmental Protection Agency's Storm Water Management Model (EPA SWMM) Version 5 was created by the Water Supply and Water Resources Division of the EPA's Risk Management Research program and is used to determine the hydraulic routing of runoff originating from the study area.

SWMM Model Input

Surface Runoff

The time series from the WWHM model were entered as inflow into the West Tidal Channel and the drainage pond for the simulation period from 1948 to 2009. The WWHM time series for P1 and P2 were entered as inflow to the drainage pond, and the time series from P3, P4, P5, and P7 were entered as inflow to the West Tidal Channel. The disconnected northern section of the West Tidal Channel will continue to drain off-site in the proposed conditions, and therefore, the storage associated with the disconnected northern section of the West Tidal Channel is not included in the SWMM model. Elevations entered into the SWMM model were converted to a datum of 100 feet to avoid conflicts within the computer application from using negative tidal stage elevations.

Tidal Channel and Drainage Pond Volumes

The section of the West Tidal Channel that will be connected to the drainage pond in the proposed condition is represented as a storage feature in the SWMM model. A stage-storage table was developed for the West Tidal Channel (Appendix C) based on LiDAR data and topographic survey data collected by Snohomish County. The volume of the West Tidal Chanel was determined in 0.5-

foot depth increments using CAD (Autodesk Civil 3D 2012). The calculated volume was reduced by 10 percent to account for the presence of vegetation, woody debris, and sediment accumulation in the West Tidal Channel. An equivalent area was calculated based on the storage volumes after the assumed 10 percent loss in storage (Appendix C) for entry into the SWMM model. The volume of the West Tidal Channel at an elevation of -0.6 feet is approximately 5.9 acre-feet for the section south of the field crossing. The southern section of the West Tidal Channel is connected to the proposed drainage pond with a 36-inch, culvert with the inlet and outlet inverts both equal to an elevation of -2.14 feet. An initial water surface elevation of -1.0 feet has been assumed as opposed to an initial ponded elevation of -2.14 feet as a conservative assumption to simulate a storm event preceding the model simulation.

A stage-storage table was developed for the drainage pond based on proposed site grading. CAD was used to determine the volume of the proposed pond at 1-foot increments. The calculated volumes were reduced by five percent to account for loss of storage due to vegetation, debris, and sediment deposition. The five percent loss of storage was assumed for the drainage pond because vegetation is expected to occupy a smaller percent of storage within the pond than what is expected in the West Tidal Channel. The deeper water depths within the pond are expected to inhibit growth of cattail or reed canary grass, the area of the pond is large relative to the perimeter where vegetation is likely to grow, and maintenance of vegetation and sediment is expected within the drainage pond. A stage–area table was developed from these reduced incremental volumes for use in SWMM. The proposed drainage pond has a live storage volume of approximately 37.4 acre-feet at an elevation of 3.0 feet. The proposed pond has one foot of dead storage, 3:1 sideslopes, and provides storage up to approximately three or four feet in elevation. The proposed drainage pond drains when the head exceeds that of the tidally-influenced Union Slough.

Culverts

Two 36-inch diameter culverts with tide gates will drain the West Tidal Channel and drainage pond system when the head in the system exceeds the tidally-influenced water surface elevation of Union Slough. One culvert will connect the West Tidal Channel to the East Tidal Channel near the approximate location of the existing agricultural ditch, and the other culvert will connect the drainage pond to Union Slough. The invert elevations of both culverts have been set at a constant -2.14 feet, which matches the outlet of the existing tide gate on Union Slough.

A third 36-inch diameter culvert connects the West Tidal Channel to the drainage pond. The culvert has an upstream and downstream invert elevation of -2.14 and will have a flap gate to prevent backflow from the pond into the West Tidal Channel.

A generic end-section entry loss coefficient of 0.5 has been assumed for all culverts. An average loss coefficient of zero has been assumed since the culverts will not include internal bends or reductions. An exit loss coefficient of 1.0 has been assumed for the culvert that connects the West Tidal Channel to the storage pond. An exit loss coefficient of 17 has been used to account for head losses due to the tide gates on the two outlet culverts. A duckbill-style tide gate is preferred, which has a linear discharge-head loss relationship according to the manufacturer's product information (Appendix D). An exit loss coefficient of 17 provides a comparable calculation of head loss for low discharge rates and a conservative calculation of head loss for larger discharge rates. The modeled tide gate head loss was compared to manufacturer's tide gate head loss data and the exit loss coefficient was evaluated by performing a sensitivity analysis (Appendix D).

Tidal Data

Simulated conditions for Union Slough were entered into SWMM as a tailwater condition time series to model the drainage system draining only during periods when the head of the system exceeds the stage on the tidally-influenced Union Slough.

Stage data collected for the Everett Riverfront Project and stage data from the Everett Water Pollution Control Facility (WPCF) were evaluated for use in these analyses. The stage data from the Everett Riverfront Project was collected during water year (WY) 2009 from the Snohomish River and provided by Snohomish County, and used by others for the Smith Island Estuary Restoration project (TetraTech, 2013A and GeoEngineers/WEST Consultants, 2011). The WPCF gage is located downstream of the Everett Riverfront Project on the Snohomish River, and the stage data was provided by the City of Everett for 2007-2013. The two sets of stage data from the Snohomish River and data from the National Oceanic and Atmosphere Administration (NOAA) Seattle, WA gage (9447130) were compared for the overlapping time period of the data sets during WY 2009. The stage data collected from the Everett Riverfront Project on the Snohomish River was consistent with the NOAA data collected on Puget Sound during tidal fluctuation and high tide periods, with the stage on the Snohomish River higher during low tides when base flow is prevalent as well as during large river flows such as the January 2009 storm event. The WPCF stage data was consistently higher than the other two by a varying amount, which may be due to datum conversion but was not able to be confirmed, and the January 2009 event was not captured in the WPCF data. The Snohomish River stage data from the Everett Riverfront project was selected based on the consistency of the high tide with the independent NOAA gage, and the higher stages due to river flow from rainfall and snowmelt.

The Snohomish River stage data from the Everett Riverfront project was repeated for each water year in the SWMM simulation to represent the tidal and river flow cycle on Union Slough. The January 2009 flood event is approximated as a 15-year return period event on the Snohomish River (Tetratech, May 2013B) and this event is repeated each January in the simulation, which provides a conservative estimate of the ability of the drainage pond to drain. The tidal statistics of the WY 2009 Snohomish River stage data was compared to nearby NOAA stations, and the use of the Snohomish River stage data results in higher tidal statistics (Appendix E).

Groundwater Seepage

Groundwater seepage rates into the West Tidal Channel and the proposed drainage pond were estimated by Shannon and Wilson (October 2013, Appendix F) by modeling the proposed site conditions in MODFLOW, and the seepage rates are included as inflow into the SWMM model to represent subsurface flow. Seepage rates were determined for both a typical fluctuating tidal condition and a flood-stage condition. The West Tidal Channel is expected to receive a base tidal seepage inflow rate of 0.048 cfs and maximum seepage rate of 0.128 cfs during flood events. The drainage pond is expected to receive a base tidal seepage inflow of 0.142 cfs and maximum seepage rate of 0.383 cfs during flood events. These seepage rates were added directly to each time step of the WWHM runoff time series for both the West Tidal Channel and Pond. The flood seepage rate was used when the stage in the Union Slough tidal time series exceeded an elevation of 10.0 feet, which was selected because it is above the mean higher high water elevation of approximately 9 feet but provides a conservative assumption of flood level seepage rates at stages which may correspond to high tides or high stage due to significant river flow.

Pump

The proposed pump station was modeled in SWMM using a pump link element. The pump element was defined as having a constant discharge, either 2 cfs or 4 cfs, regardless of Union Slough tidal stage. The pump float elevations were set so that the pump turned on when the water surface elevation in the pond exceeded -0.6 and switched off when the water surface elevation was drawn down to -1.0.

Modeled Scenarios

Four drainage alternative scenarios are investigated: 1) the drainage pond with one gravity outlet, 2) the proposed pond with two gravity outlets, 3) the drainage pond with a pump station with a total outflow of two cfs and two gravity outlets, and 4) the pond with a pump station with a total outflow of four cfs and two gravity outlets. Each scenario uses the same sub-basins, modeled inflow runoff and characteristics for the West Tidal Channel, proposed drainage pond, and culvert connecting the channel to the pond, and gravity outlet characteristics (size and invert). Groundwater seepage and Union Slough tide stage are the same in all scenarios. In addition, a sensitivity analysis of the tide gate head loss coefficients was performed to determine the effect of the model assumptions and tide gate on the modeled water surface elevations and discharges from the drainage pond.

The WWHM runoff volumes from the 100-year or larger flood event were also modeled in SWMM. The December 1996 event was modeled using the original simulated stage in Union Slough, and also modeled by assuming a seven-day period of flood conditions on Union Slough when the drainage pond would not drain by gravity and flood-level seepage rates. The start of the simulated seven days of flood conditions on Union Slough precedes the December 1996 rainfall event by approximately two days to model a partially-filled pond condition at the start of rainfall as a conservative assumption. The peak water surface elevations for this flood event over the seven-day duration were evaluated for 1)the two tide gate and 2) the pump station with two tide gate alternatives.

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Section 5—Drainage Analysis Results

Drainage Basin Analysis and WWHM Results

The drainage areas measured from the proposed conditions sub-basin delineation are shown in Table 1, and a summary of the peak discharge rates from the hydrologic analysis of the study area under the proposed conditions are given in Table 2. A summary of modeled results from WWHM for the 1948-2009 simulation period are provided in Appendix F.

The December 1996 rainfall depths recorded by the National Weather Service were found to be larger than the 100-year rainfall depths over a 24-hour period, and over a 4-day period, and comparable to 100-year rainfall depths over a 2-day and 7-day period (Table 3). The December 1996 rainfall data was the event of record for the gage and was used to represent 100-year or larger flood conditions within the study area. The simulated runoff volumes and peak discharges entering the West Tidal Channel and drainage pond for the December 1996 rainfall event are shown in Table 4. The peak discharge rate of 28.7 cfs entering the West Tidal Channel modeled during the December 1996 event is higher than the 100-year peak discharge of 25.6 cfs estimated by WWHM, which may be attributed to the different methods of estimating return period peak discharges by using a Log-Pearson Type III distribution compared to modeled outflow which is based on HSPF calculations.

Table 1. Proposed conditions sub-basin areas and land use.

Sub-basin	SAT, Pasture, Flat (ac)	SAT, Pasture, Steep (ac)	Roads, Flat (ac)	Driveways, Flat (ac)	Pond (ac)	Total Area (ac)	Impervious Coverage	Impervious and Pond Coverage
P1	6.8	1.1	0.5	0.0	0.0	8.4	5.6%	5.6%
P2	14.7	2.2	0.8	1.3	7.7	26.7	8.1%	37.0%
P3	5.8	2.2	0.0	1.6	0.0	9.6	16.7%	16.7%
P4	45.7	0.0	0.0	2.9	3.7	52.4	5.6%	12.7%
P5	19.0	1.0	0.0	1.0	0.0	21.0	4.9%	4.9%
P6	1.7	1.4	1.3	0.0	0.4	4.9	27.5%	35.2%
P7	14.4	0.5	2.0	1.5	0.0	18.4	19.0%	19.0%
P8	14.0	1.0	2.2	1.4	0.5	19.1	18.7%	21.3%
Total	122.2	9.3	6.8	9.8	12.3	160.4	10.3%	18.0%

Table 2. Proposed conditions sub-basin peak discharge rates.

Sub-basin ID	Total Area (ac)	Return Period Flow (cfs)					
		2-year	5-year	10-year	25-year	50-year	100-year
P1	8.4	0.4	0.7	1.0	1.3	1.7	2.1
P2	26.7	4.5	6.2	7.4	9.1	10.4	11.8
P3	9.6	0.9	1.3	1.7	2.1	2.5	2.9
P4	52.4	3.5	5.3	6.7	8.9	10.7	12.8
P5	21.0	0.9	1.5	2.1	3.0	3.8	4.8
P6	4.9	0.8	1.2	1.4	1.7	2.0	2.3
P7	18.4	1.7	2.5	3.1	3.9	4.5	5.3
P8	19.1	2.0	2.8	3.5	4.3	5.1	5.9
P1, P2 (to Pond)	35.1	4.9	6.8	8.2	10.2	11.8	13.5
P3, P4, P5, P7 (to West Tidal Channel)	101.4	7.0	10.5	13.3	17.6	21.4	25.6
Total Inflow to West Tidal Channel and Pond	136.5	11.8	17.3	21.5	27.8	33.1	39.1

Table 3. Comparison of 100-year precipitation depths to observed precipitation from the NWS Everett station for the 1996 event.

Storm Duration	Dec. 1996 Precip Depth (in)	100-year Precip Depth (in)
6-hour	1.48	1.85
24-hour	3.64	3.40
2-day	5.33	6.00
4-day	7.38	6.50
7-day	7.86	8.00

Table 4. Peak Discharges and Runoff volumes for the 1996 event.

	Basins P1, P2	Basins P3, P4, P5, P7
Peak Discharge Rate (cfs)	11.5	28.7
Max. 24-hour Runoff Volume (acre-feet)	6.21	14.60

SWMM Results

Tide Gate Loss Coefficient Sensitivity Analysis

A sensitivity analysis was performed to determine the effect of the exit loss coefficient for the culverts with tide gates on the modeled water surface elevations. The SWMM model uses a constant exit loss coefficient when calculating discharge from the culverts. The manufacturer of the duck-bill type tide gate provided head loss data that is linear relative to discharge rates under submerged conditions (Appendix D), and the coefficient for head loss is therefore higher at low discharge rates and decreases with greater discharge rates. An initial SWMM simulation with a exit loss coefficient of 5.5 provided an initial range of discharge rates from the culverts of the drainage pond. The 5th, 50th, and 95th percentile peak discharge rates from the initial SWMM simulation were selected to calculate head loss coefficients from the manufacturer's data and perform the sensitivity analysis. The 5th, 50th, and 95th percentile corresponded to approximately a 2 cfs, 4 cfs, and 7 cfs respectively. The head loss coefficients calculated for the discharges from the manufacturer's data corresponded to 61, 31, and 17 respectively. A comparison of the use of a constant head loss coefficient with the manufacturer's data demonstrates that the error in head loss is relatively small at low discharges, but is can produce significant error at large discharges by using a head loss coefficient that is too high. Based on the sensitivity analysis, the head loss coefficient for the tide gate was selected as 17.0 because it provided reasonable head losses for the range of discharges expected from the culverts, without significantly over-estimating head loss during the largest discharge rates.

Water Surface Elevations

The modeled results indicate that the peak water surface elevations for the simulation period of 1948-2009 occur during the December 1996 event, with the water surface reaching 2.21 and 1.66 feet for the one and two gravity pipe alternatives, respectively, while the pump systems maintain peak water surface elevations at 0.91 and 0.49 feet for the 2 cfs and 4 cfs pump station outflow, respectively (Table 5, Appendix G). The peak water surface elevations are below the adjacent ground surface elevation of approximately 4 feet, indicating that the tidal channel and drainage pond system do not overtop during the 60-year simulation even for the one tide gate alternative. The daily exceedance for the water surface elevations indicates the percent of days during the simulation where the water surface reaches a level higher than the elevation. Any day where the elevation is exceeded is counted in the analysis, whether the elevation was exceeded for minutes or several hours.

A comparison of the exceedance frequency for the water surface elevations within the West Tidal Channel for the drainage system design alternatives indicates that the two pipe gravity system reduces the frequency of days with peak water surface elevations above -0.6 feet from approximately 70 percent with a one pipe system to 30 percent with a two pipe system, including seepage rates (Figure 5, Appendix I). The addition of a pump system with 2 cfs outflow shows that the water surface elevation is maintained at or below the -0.6 feet drain tile invert elevation for the frequent storm events and the drain tile invert is exceeded during the largest flood events. The additional outflow of a 4 cfs pump system drains the pond faster for the more frequent storm events, and only shows a significant benefit over the 2 cfs pump capacity for the largest flood events such as the December 1996 flood event.

The results from modeling the December 1996 rainfall event with seven days of flood conditions on Union Slough indicate that water surface elevations would not overtop the drainage pond or West Tidal Channel with a two tide gate gravity system and no pump station, but would inundate the tile drains for an extended time (Table 6, Appendix H). The use of a pump station with a 2 cfs total outflow reduces peak water surface elevations by about two feet compared to the two tide gate system and significantly reduces the duration that water levels exceed the tile drains following the seven-day flood conditions.

Table 5. Comparison of peak water surface elevations for the simulated period from 1948-2009 for the drainage system design alternatives.

	1 Tide Gate Outlet	2 Tide Gate Outlets	2 cfs Pump, 2 Tide Gate Outlets	4 cfs Pump, 2 Tide Gate Outlets
West Tidal Channel Max. Water Surface Elev. (NAVD88)	2.21	1.66	0.91	0.49
Drainage Pond Max. Water Surface Elev. (NAVD88)	2.21	1.66	0.91	0.48
Total Pump "On" Events	-	-	1184	1322
Total Pump Operation Time (hours)	-	-	35519	17617
Percent of Time Pump in Operation	-	-	6.6%	3.3%
Average Pumping Duration per Event(hours)	-	-	30	13

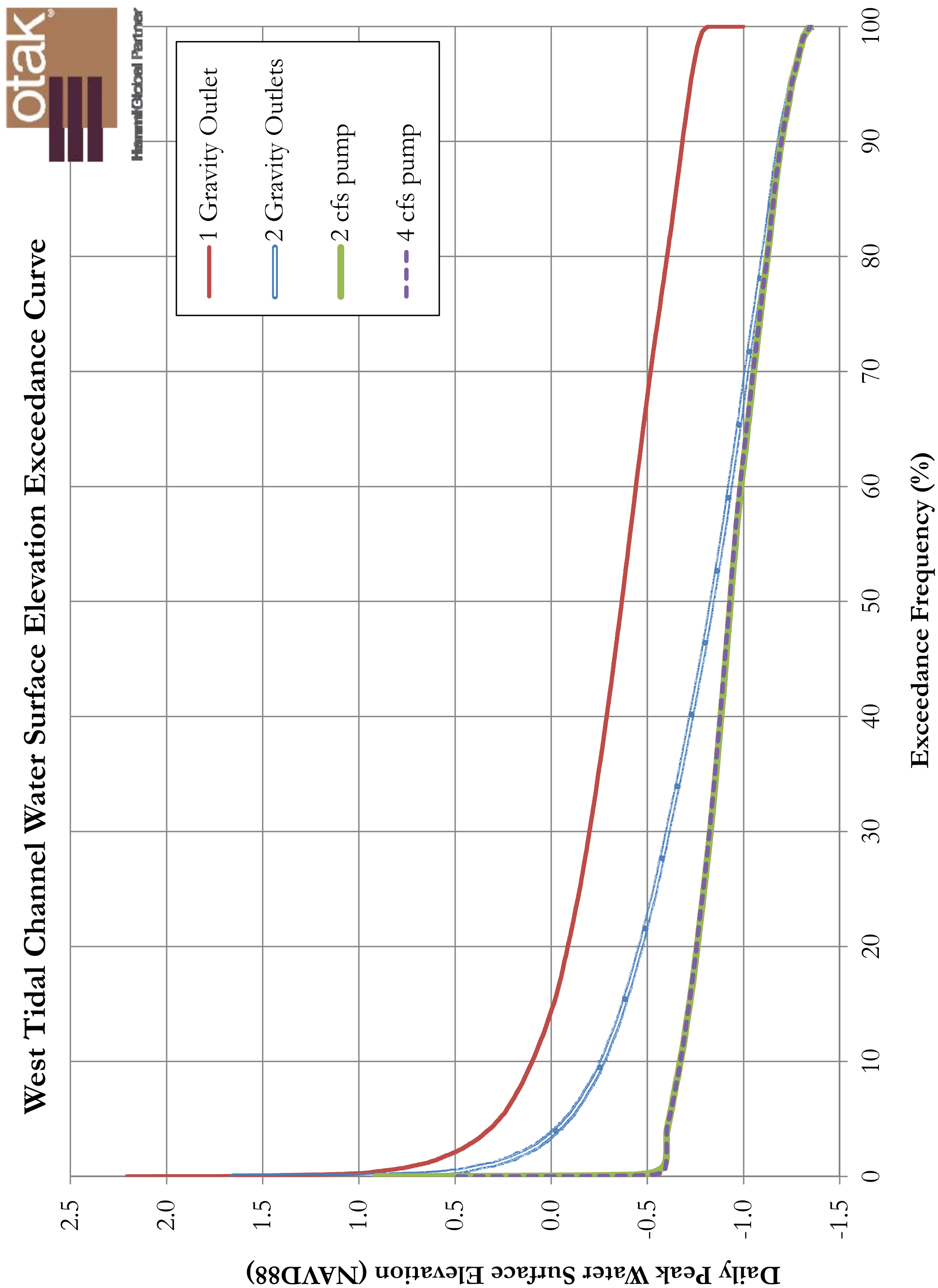

Figure 5. Exceedance Frequency for Water Surface Elevations within the West Tidal Channel.

Table 6. The peak water surface elevations and pump operations for a simulated 7-day flood conditions on Union Slough and the December 1996 rainfall event.

	2 Tide Gate Outlets	2 cfs Pump, and 2 Tide Gate Outlets
West Tidal Channel Max. Water Surface Elev. (NAVD88)	3.45	1.52
Drainage Pond Max. Water Surface Elev. (NAVD88)	3.45	1.52
Total Pump "On" Events	-	4
Total Pump Time (hours)	-	386

Conclusions

The hydrologic and hydraulic analysis of the study area indicates that the use of a two tide gate system reduces water surface elevations within the West Tidal Channel and drainage pond by a significant amount (reducing the frequency of days above a tile drain invert from approximately 70 percent to 30 percent). Based on conservative assumptions of seepage rates from high groundwater conditions, saturated soil conditions, the potential for runoff to flow from the west ditch to the West Tidal Channel, and high stage levels on Union Slough, a pump station will be required for water surface elevations to be maintained below the drain tile inverts (represented as -0.6 feet in elevation) currently serving the adjacent tree nursery property.

The water surface elevations can be managed when a pump system with a total output of two cfs is operated as a contingency measure. The simulation indicates that when the pump is set to turn on when water surface elevations are near the tile drain inverts, the two cfs flow rate provides the capacity necessary to maintain surface water below the tile drains for most events except for the largest flood events such as the December 1996 event. The use of a four cfs capacity pump system (such as two, 2 cfs pumps) drains the pond faster and maintains a lower peak water surface elevation in the channel during the large flood events, but does not provide significant benefit for the more frequent conditions.

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Appendix A.
Hima Nursery Field Survey Data

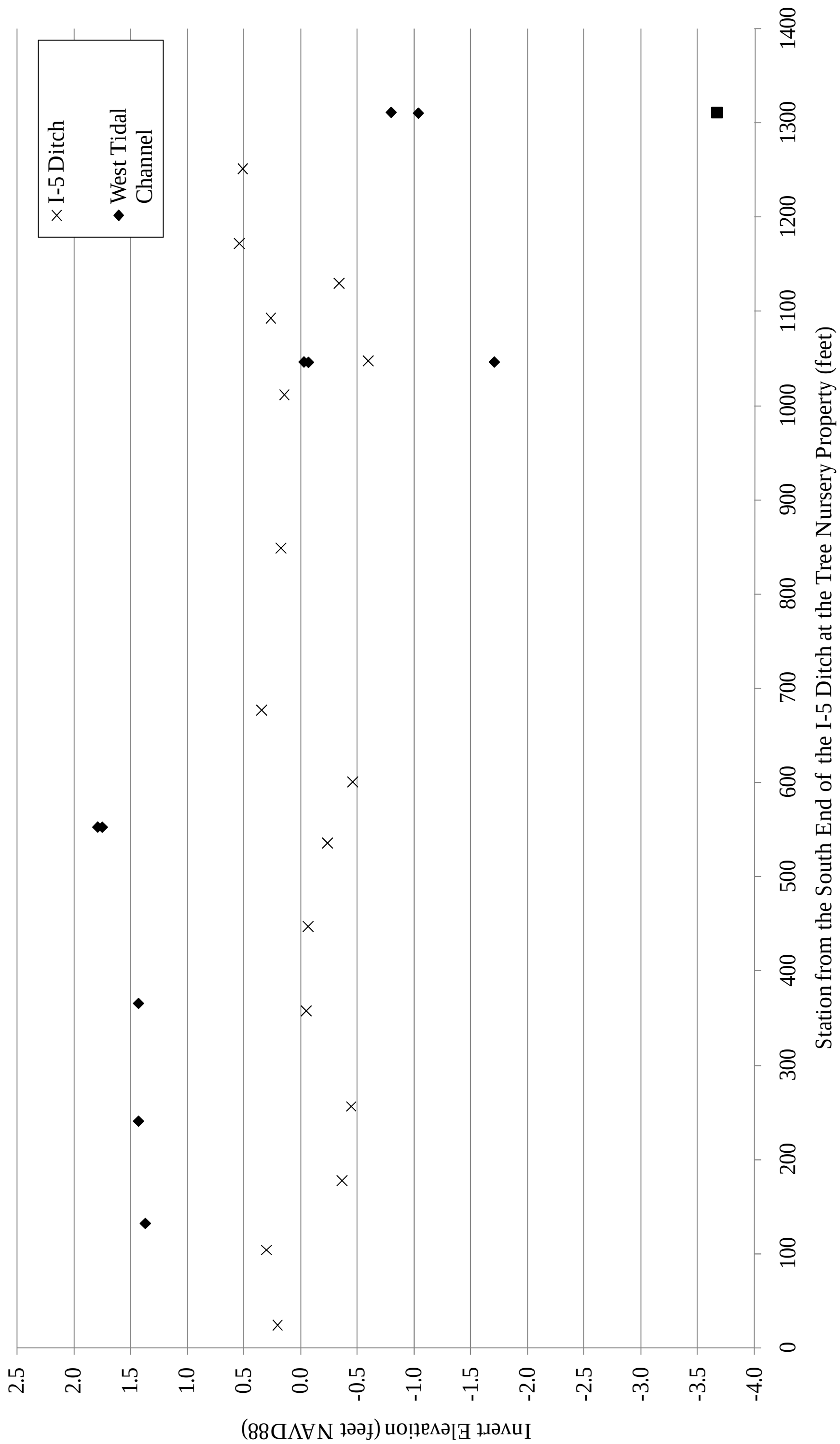
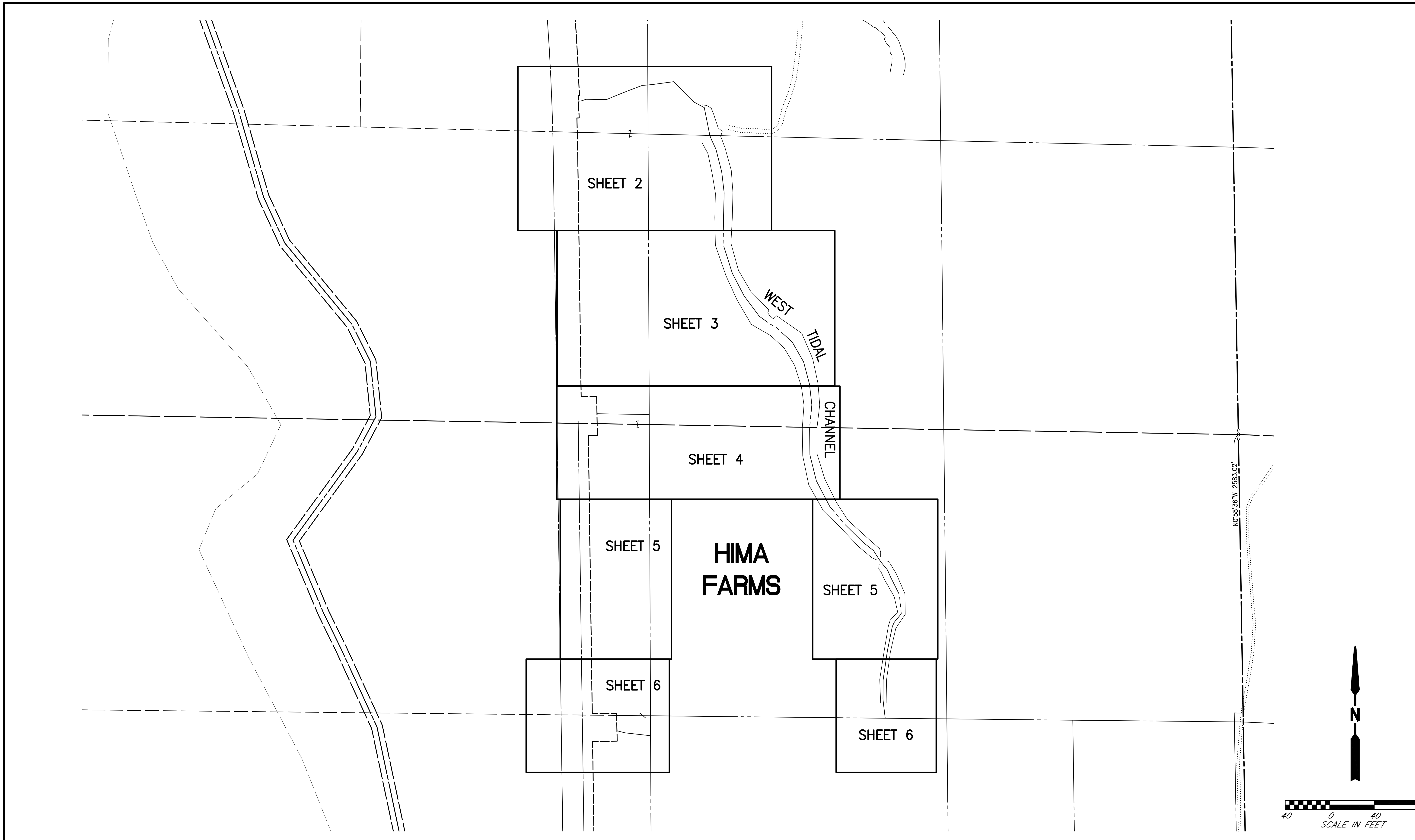


Figure A-1. Drain tile invert elevations at the tree nursery property.



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KEY MAP

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SMITH ISLAND
ESTUARY RESTORATION
HIMA FARMS SURVEY DATA

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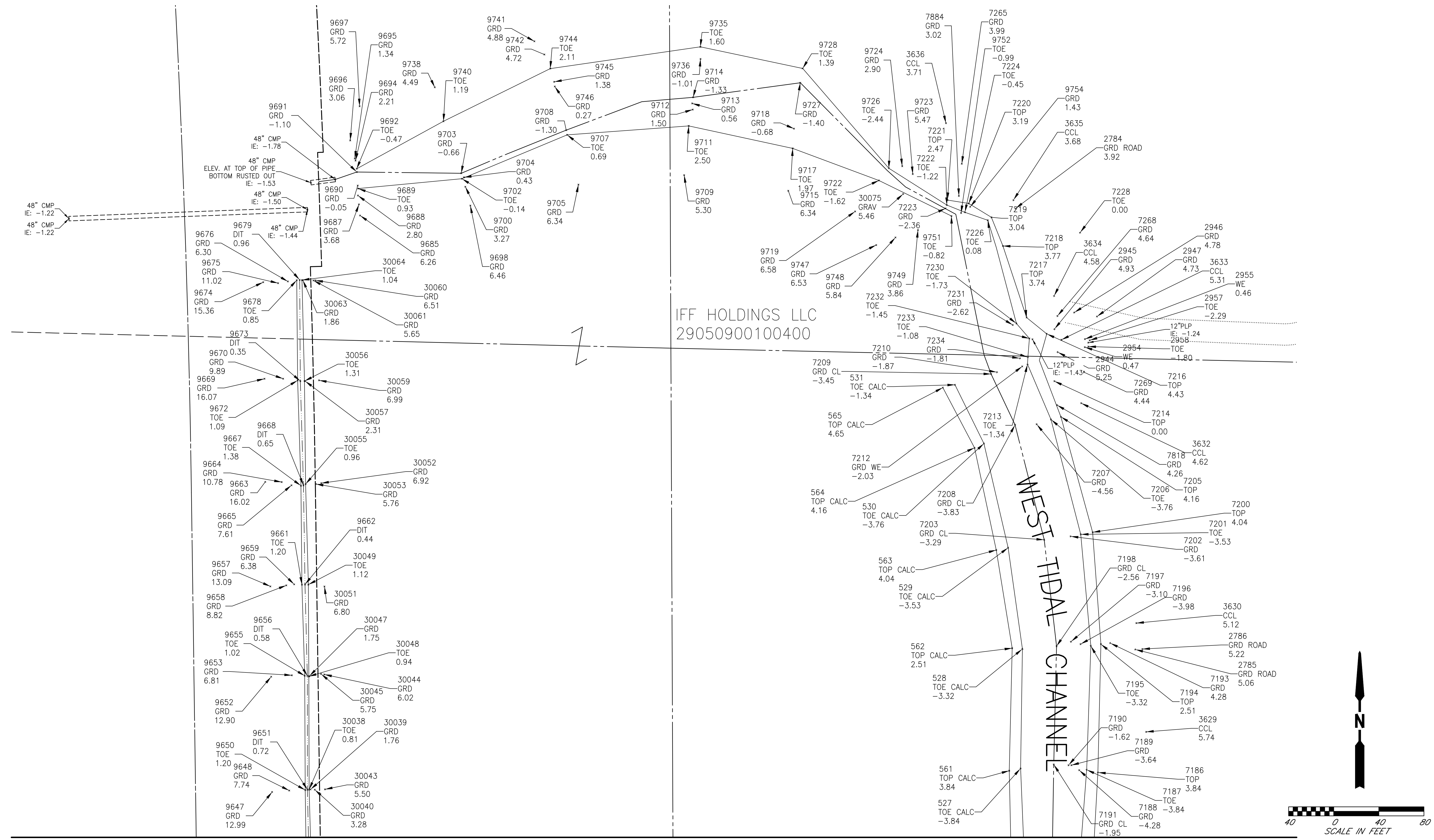

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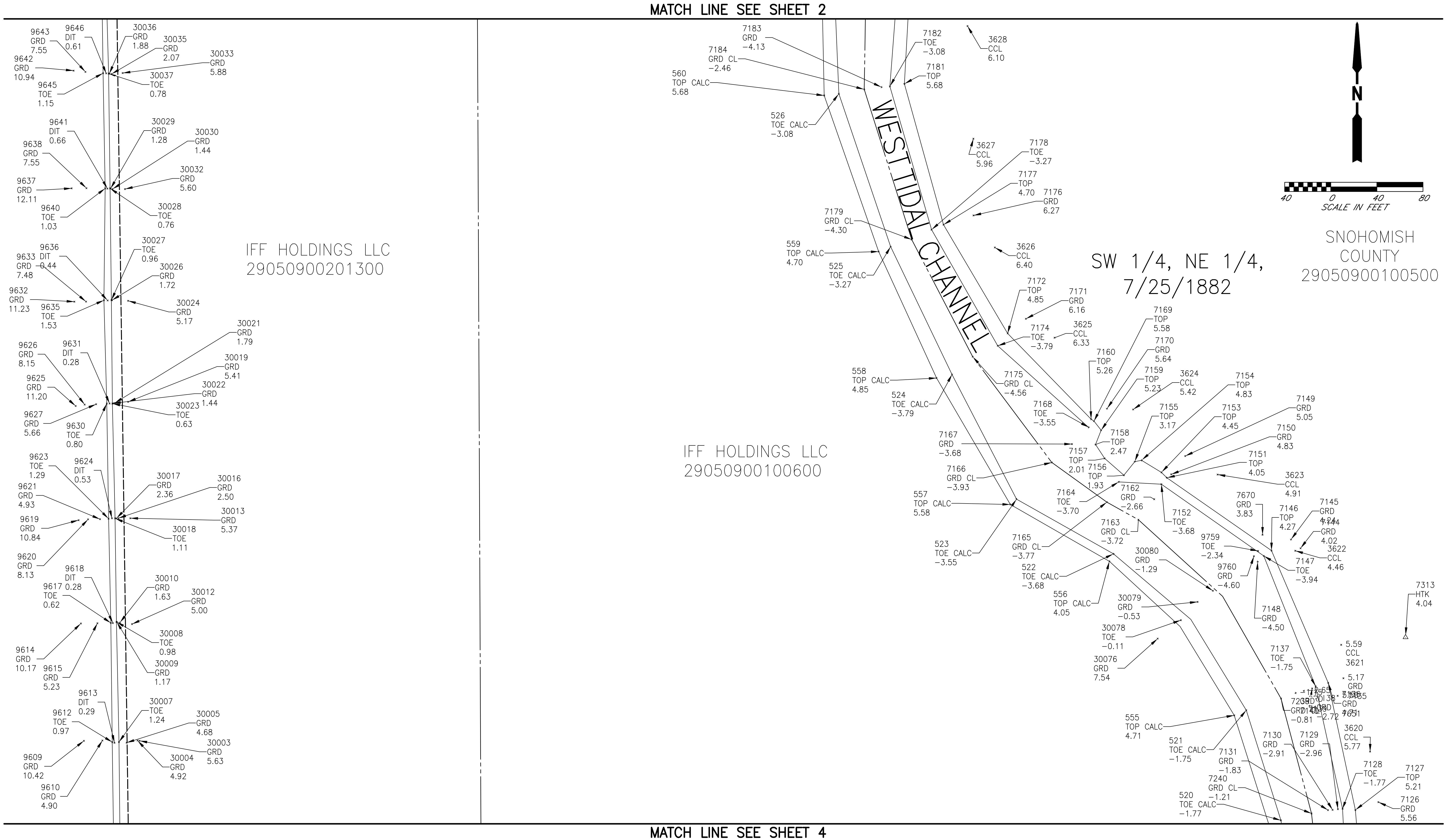

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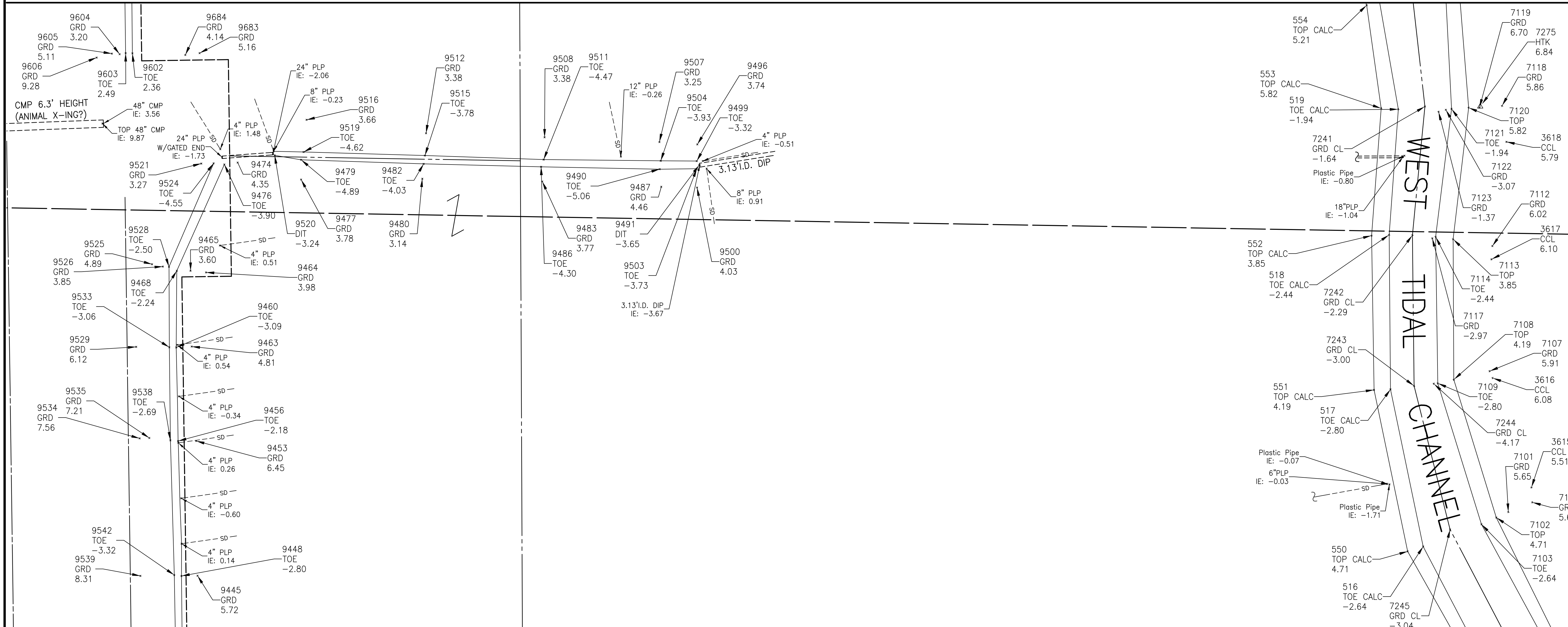

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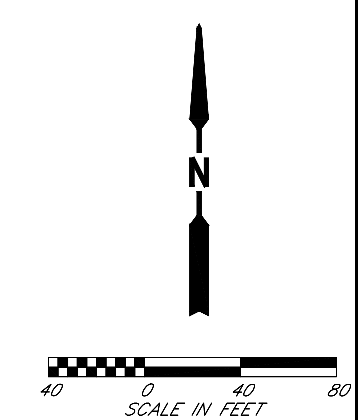

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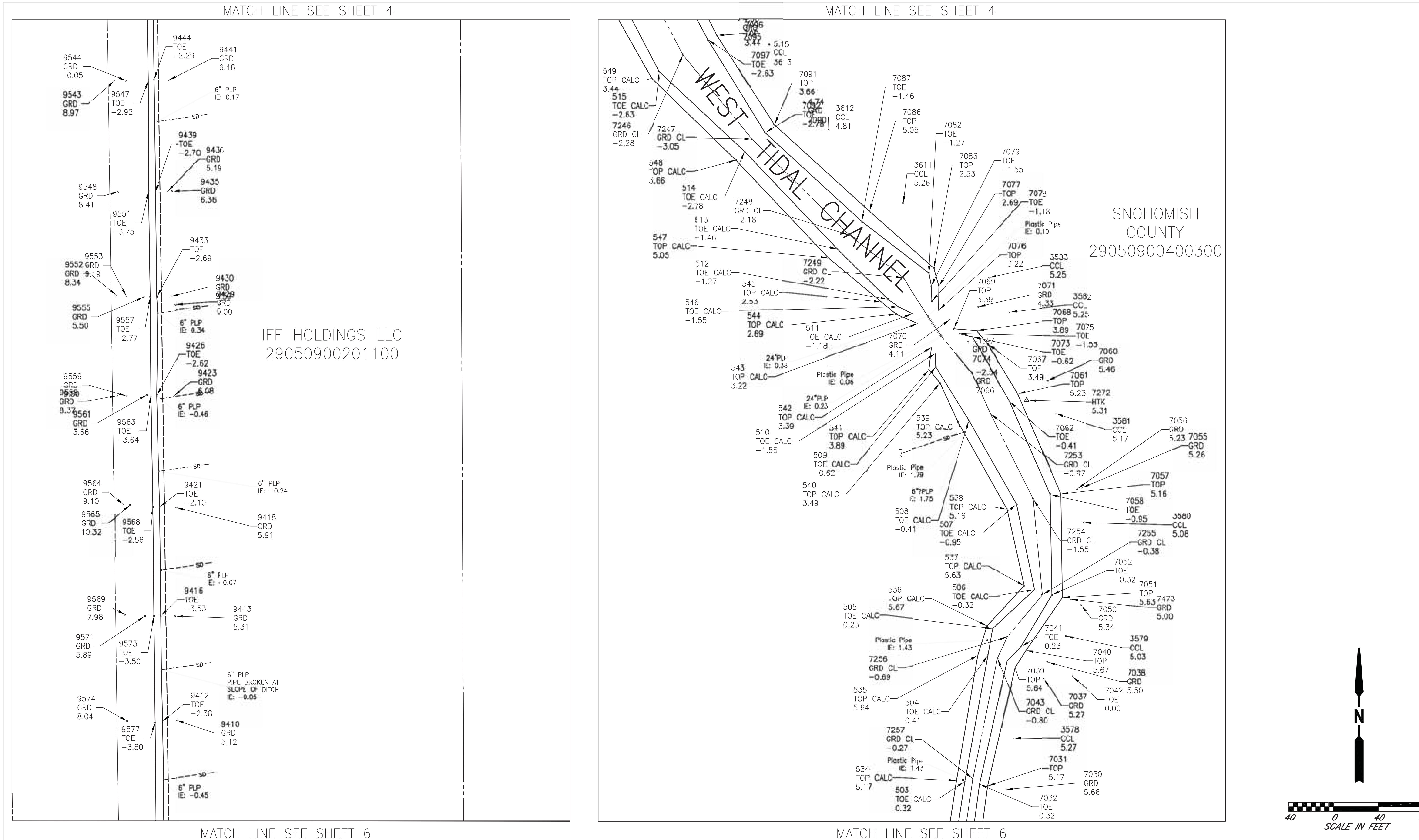

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SMITH ISLAND
ESTUARY RESTORATION

HIMA FARMS SURVEY DATA

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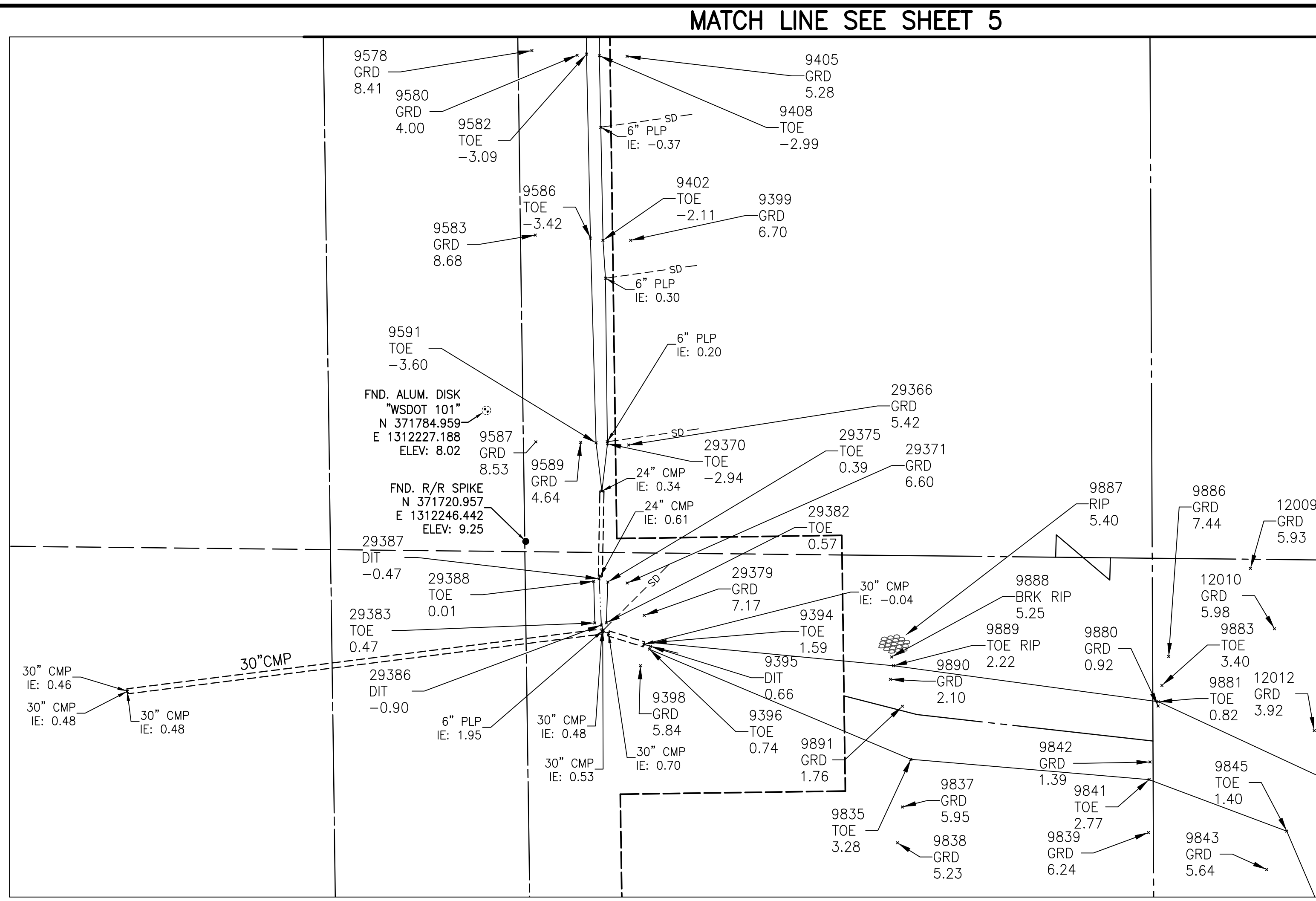

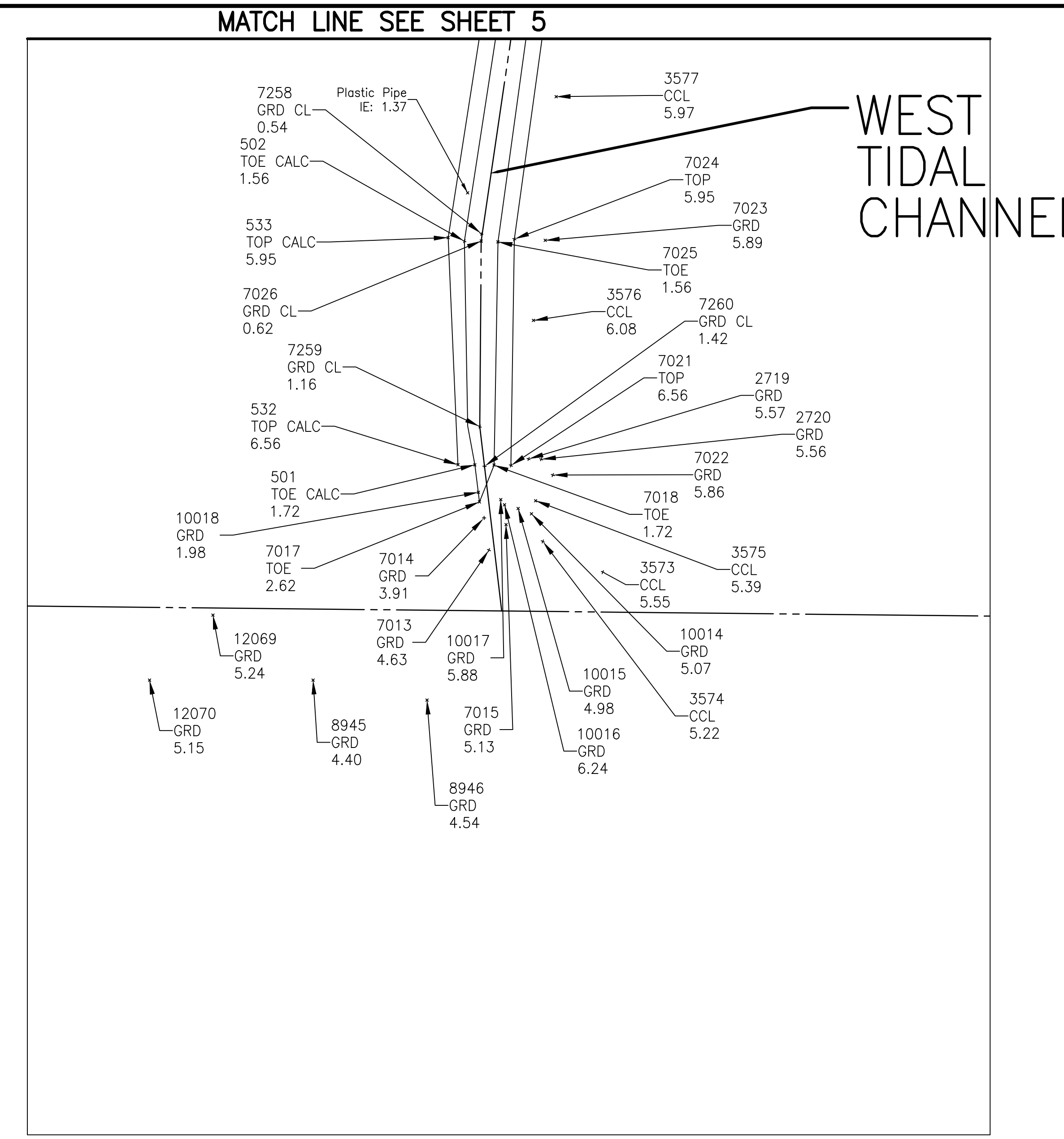

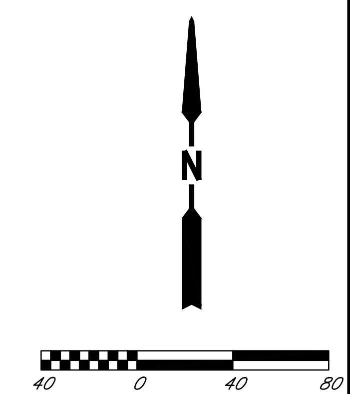

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Appendix B
Photo Documentation

Photo B-1. The West Tidal Channel looking South from approximately Station 33+00 of the proposed setback dike in February 2013.

Photo B-2. The West Tidal Channel at the same location as Photo 1 in May of 2013.

Photo B-3. The West Tidal Channel at the same location as Photos B-1 and B-2 in September of 2013.

Photo B-4. The east-west agricultural ditch connecting the West Tidal Channel and East Tidal Channel with 12" pipes connection at either end, looking east.

Photo B-5. Tile drain outlets in the West Tidal Channel in June 2013. The tile drain with invert -1.71 feet is sediment-colored at the bottom of the staff, while the tile drain with invert elevation -0.07 feet is the green PVC pipe.

Appendix C.
Tidal Channel, Drainage Pond, and Depression Storage Calculations

Table C-1. Depression storage calculated within sub-basin P5 to determine approximate runoff volumes and elevations required for stormwater to drain north to the West Tidal Channel..

Elevation (NAVD88)	Storage (ac-ft)
1.5	0.00
2	0.01
2.5	0.02
3	0.04
3.5	0.29
3.8	1.01
4	1.49
4.5	4.08
5	8.70

Table C-2. Stage-storage relationship developed for the section of the West Tidal Channel connected to the drainage pond with a 10% reduction in storage assumed.

Stage (NAVD88 Feet)	Storage Volume (ac-ft)	Volume - 10% Loss of Storage (ac-ft)	Equivalent Area (ac)
-4.50	0.00	0.00	0.00
-4.00	0.04	0.03	0.11
-3.50	0.29	0.26	0.62
-3.00	0.82	0.74	1.04
-2.50	1.57	1.42	1.50
-2.00	2.59	2.33	1.91
-1.50	3.80	3.42	2.26
-1.00	5.16	4.64	2.51
-0.50	6.65	5.98	2.73
0.00	8.23	7.41	2.89
0.50	9.90	8.91	3.04
1.00	11.66	10.49	3.21
1.50	13.50	12.15	3.36
2.00	15.44	13.89	3.52
2.50	17.46	15.71	3.67
3.00	19.56	17.61	3.84
3.50	21.88	19.69	4.15
4.00	24.32	21.88	4.48

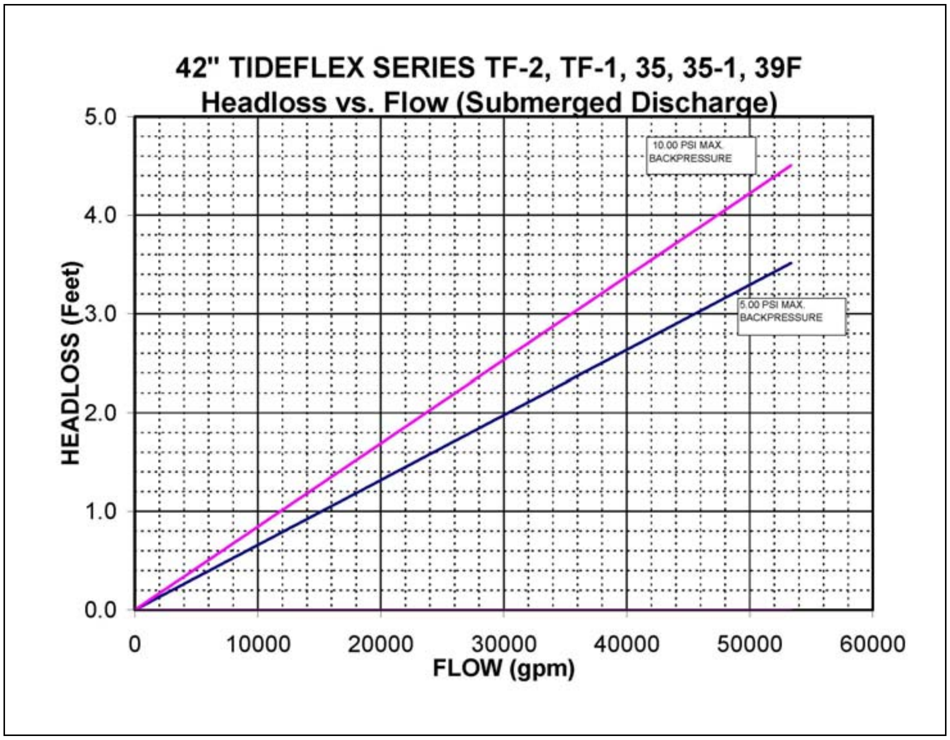
Table C-3. Stage-storage relationship developed for the drainage pond with a 5% reduction in storage assumed.

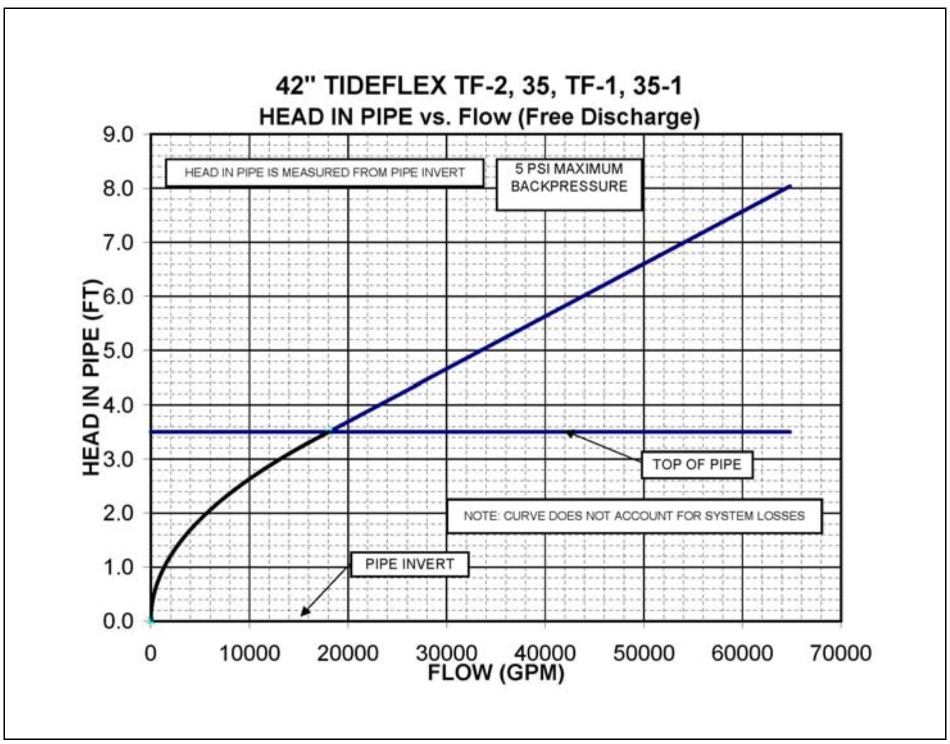
Stage (NAVD88 Feet)	Storage Volume (ac-ft)	Volume - 5% Loss of Storage (ac-ft)	Equivalent Area (ac)
-3.14	0.00	0.00	6.68
-3.00	0.99	0.94	6.68
-2.00	8.13	7.72	6.78
-1.00	15.44	14.67	6.95
0.00	22.94	21.79	7.12
1.00	30.61	29.08	7.29
2.00	38.46	36.53	7.46
3.00	46.48	44.16	7.63
4.00	54.69	51.95	7.79

Appendix D.
Tide Gate Head Loss Data and Sensitivity Analysis

Appendix D.

Figure D-1. Manufacturer's Head loss data.





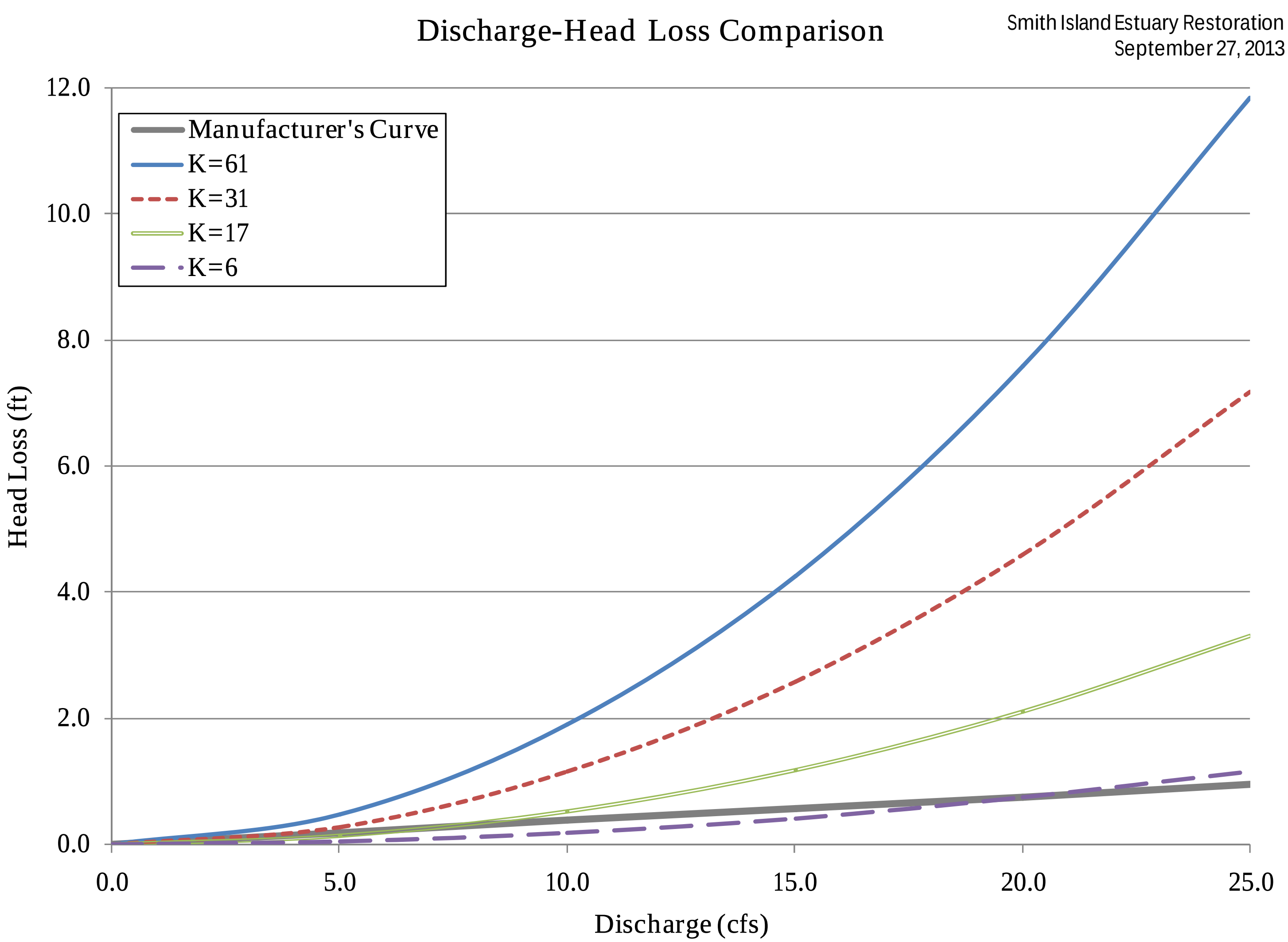


Figure D-2. Comparison of head loss to discharge for varying loss coefficients and the manufacturer's data.

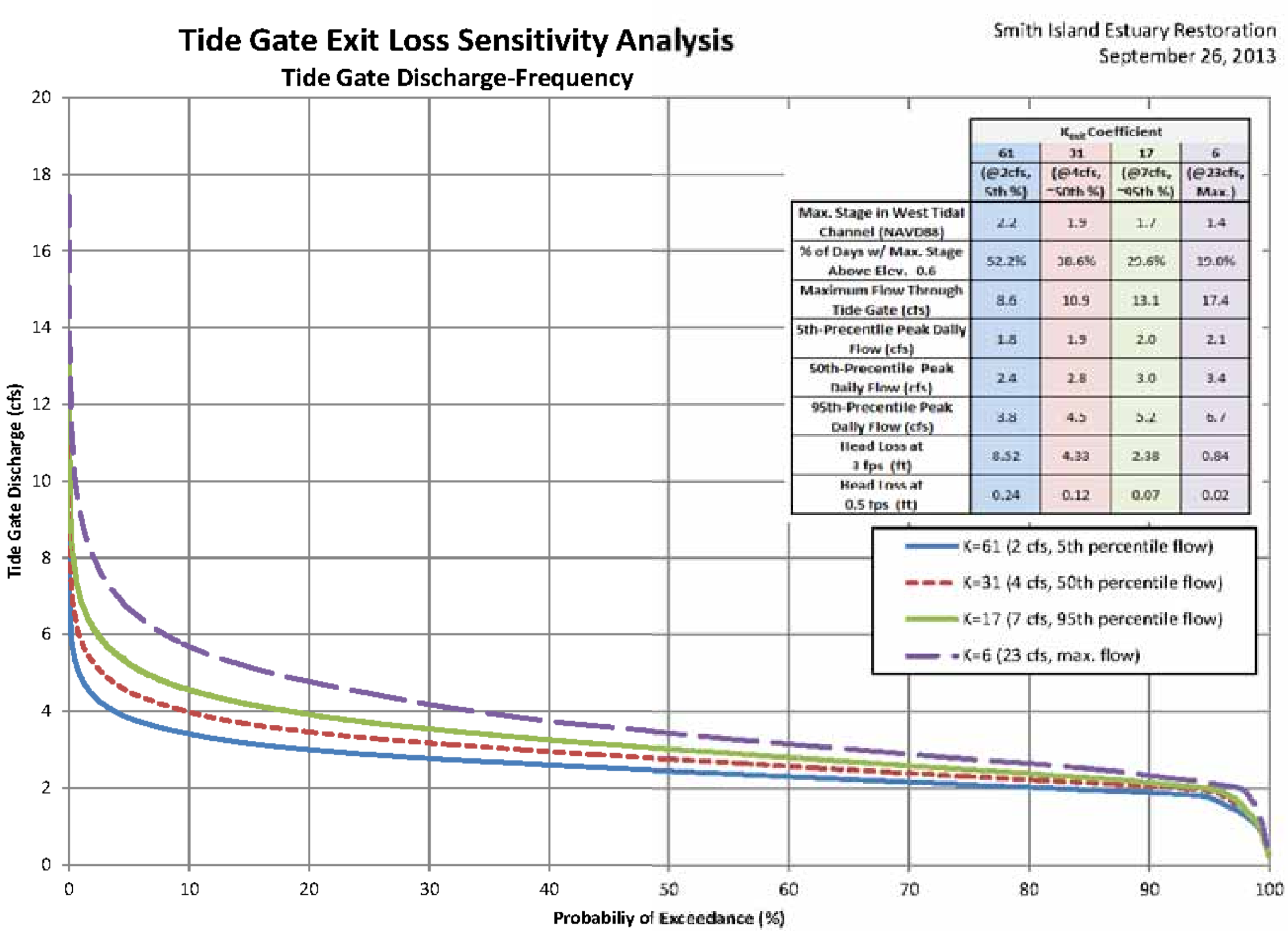


Figure D-3. Sensitivity of modeled discharge exceedance frequencies for each tide gate to varying head loss coefficients.

Appendix E.
Tide Station Comparison

Statistics for the tide stations in Seattle (National Oceanic and Atmospheric Administration (NOAA) Station (9447130, Verified data), Everett (9447659, predicted tide), Marysville (9447729, predicted tide), and Port Townsend (9444900, Verified data) are compared to the Snohomish River (WY 2009) stage data used for Union Slough (Table E-1). Verified stage indicates the data was quality controlled by NOAA; predicted indicates the results of a tide stage model, used when no verified data exists for the period of record.

Table E-1. Comparison of Tidal Statistics of the Snohomish River stage data to NOAA stations.

	Water Surface Elevation (feet NAVD88)				
	Seattle	Everett	Marysville	Port Townsend	Snohomish River (WY 2009)
MHHW	9.02	9.06	9.17	7.41	9.21
MHW	8.15	8.18	8.3	6.73	
MTL	4.32	4.48		4.06	4.80
MLW	0.49	0.77		1.39	
MLLW	-2.34	-2.03		-1.11	-1.02

The tide statistics calculated for the Snohomish River WY 2009 stage data selected for SWMM modeling are higher than the statistics calculated than the NOAA stations, and represents a conservative estimate of tidal stage.

The Seattle District U.S. Army Corps of Engineers (USACE) conducted a tidal surge analysis for the Snohomish River in 2000 that established tide elevations used for the calibration of the downstream boundary conditions for the FEMA Flood Insurance Study on the Snohomish River (Table E-2) (WEST, 2001).

Table E-2: USACE Snohomish River Tidal Surge Elevations.

	Snohomish River Stage	
	Elevation (feet NGVD)	Elevation (feet NAVD88)
500-year	8.7	12.38
100-year	8.4	12.08
50-year	8.2	11.88
10-year	7.8	11.48
MHHW	5.2	8.88

The exceedance frequency for the simulated stage on Union Slough based on the selected Snohomish River stage data is shown in Figure E-1.

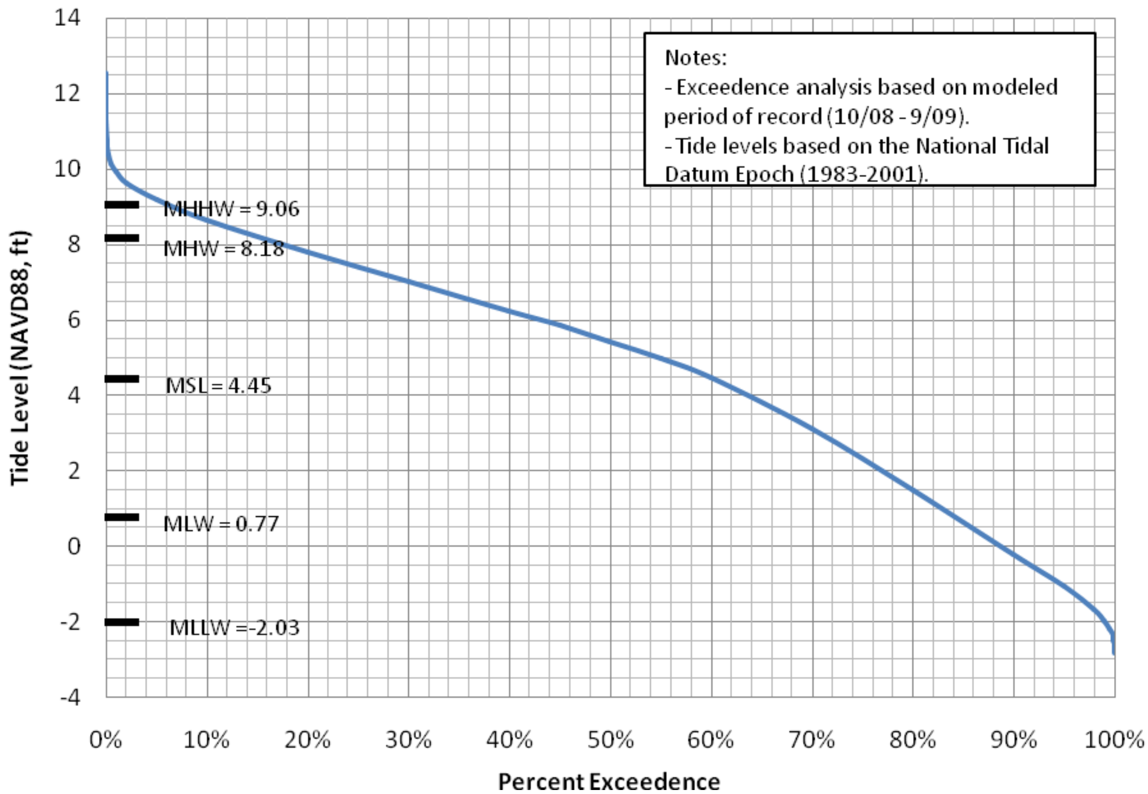


Figure E-1. Hourly percent exceedance for stage levels in the selected stage data set for WY 2009.

References:

WEST Consultants, Inc, 2001. Technical Support Data Notebook for Snohomish County, Washington, Restudy Flood Insurance Study.

Appendix F.
Summary of WWHM Hydrologic Results

WWHM2012
PROJECT REPORT

Project Name: SI Interior Drainage
Site Name: Smith Island Estuary
Site Address:
City : Everett
Report Date: 10/3/2013
Gage : Everett
Data Start : 1948/10/01
Data End : 2009/09/30
Precip Scale: 1.00
Version : 2013/08/08

PREDEVELOPED LAND USE

Name : Basins P1 P2
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Forest, Flat	35.115
Pervious Total	**35.115**

Impervious Land Use	Acres
Impervious Total	**0**
Basin Total	**35.115**

Element Flows To:

Surface	Interflow	Groundwater

Name : Basins P3 P4 P5 P7
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Forest, Flat	101.351
Pervious Total	**101.351**

Impervious Land Use	Acres
Impervious Total	**0**
Basin Total	**101.351**

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P1
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Forest, Flat	8.39
Pervious Total	**8.39**

Impervious Land Use	Acres
Impervious Total	**0**

Basin Total **8.39**

Element Flows To:
Surface **Interflow** **Groundwater**

Name : Basin P2
Bypass: No

GroundWater: No

Pervious Land Use	**Acres**
SAT, Forest, Flat	**26.73**

Pervious Total **26.73**

Impervious Land Use	**Acres**

Impervious Total **0**

Basin Total **26.73**

Element Flows To:
Surface **Interflow** **Groundwater**

Name : Basin P3
Bypass: No

GroundWater: No

Pervious Land Use	**Acres**
SAT, Forest, Flat	**9.59**

Pervious Total **9.59**

Impervious Land Use	**Acres**

Impervious Total **0**

Basin Total **9.59**

Element Flows To:
Surface **Interflow** **Groundwater**

Name : Basin P4
Bypass: No

GroundWater: No

Pervious Land Use	**Acres**
SAT, Forest, Flat	**52.35**

Pervious Total **52.35**

Impervious Land Use	**Acres**

Impervious Total **0**

Basin Total **52.35**

Element Flows To:
Surface **Interflow** **Groundwater**

Name : Basin P5

Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Forest, Flat	21

Pervious Total 21

Impervious Land Use	Acres

Impervious Total 0

Basin Total 21

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P6
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Forest, Flat	4.89

Pervious Total 4.89

Impervious Land Use	Acres

Impervious Total 0

Basin Total 4.89

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P7
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Forest, Flat	18.41

Pervious Total 18.41

Impervious Land Use	Acres

Impervious Total 0

Basin Total 18.41

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P8
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Forest, Flat	19.06

Pervious Total 19.06

Impervious Land Use	Acres
Impervious Total	0
Basin Total	19.06

Element Flows To:
Surface Interflow Groundwater

MITIGATED LAND USE

Name : Basin P1
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	6.84
SAT, Pasture, Steep	1.08
Pervious Total	7.92

Impervious Land Use	Acres
ROADS FLAT	0.47
Impervious Total	0.47
Basin Total	8.39

Element Flows To:
Surface Interflow Groundwater

Name : Basin P2
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	14.66
SAT, Pasture, Steep	2.17
Pervious Total	16.83

Impervious Land Use	Acres
ROADS FLAT	0.83
DRIVEWAYS FLAT	1.33
POND	7.73
Impervious Total	9.89
Basin Total	26.72

Element Flows To:
Surface Interflow Groundwater

Name : Basin P3
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	5.84
SAT, Pasture, Steep	2.16
Pervious Total	8

Impervious Land Use	Acres
DRIVEWAYS FLAT	1.6

Impervious Total 1.6

Basin Total 9.6

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P4
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	45.7

Pervious Total 45.7

Impervious Land Use	Acres
DRIVEWAYS FLAT	2.95
POND	3.7

Impervious Total 6.65

Basin Total 52.35

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P5
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	18.96
SAT, Pasture, Steep	1.02

Pervious Total 19.98

Impervious Land Use	Acres
DRIVEWAYS FLAT	1.02

Impervious Total 1.02

Basin Total 21

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P6
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	1.75
SAT, Pasture, Steep	1.42

Pervious Total 3.17

Impervious Land Use	Acres
ROADS FLAT	1.33
DRIVEWAYS FLAT	0.01

POND 0.38

Impervious Total 1.72

Basin Total 4.89

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P7
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	14.45
SAT, Pasture, Steep	.45

Pervious Total 14.9

Impervious Land Use	Acres
ROADS FLAT	1.98
DRIVEWAYS FLAT	1.52

Impervious Total 3.5

Basin Total 18.4

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin P8
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	14.01
SAT, Pasture, Steep	.99

Pervious Total 15

Impervious Land Use	Acres
ROADS FLAT	2.17
DRIVEWAYS FLAT	1.39
POND	0.51

Impervious Total 4.07

Basin Total 19.07

Element Flows To:

Surface	Interflow	Groundwater

Name : Basins P1 P2
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	21.5
SAT, Pasture, Steep	3.252

Pervious Total 24.752

Impervious Land Use	Acres

ROADS FLAT	1.304
DRIVEWAYS FLAT	1.328
POND	7.731

Impervious Total 10.363

Basin Total 35.115

Element Flows To:

Surface	Interflow	Groundwater

Name : Basins P3 P4 P5 P7
Bypass: No

GroundWater: No

Pervious Land Use	Acres
SAT, Pasture, Flat	84.95
SAT, Pasture, Steep	3.628

Pervious Total 88.578

Impervious Land Use	Acres
ROADS FLAT	1.981
DRIVEWAYS FLAT	7.089
POND	3.703

Impervious Total 12.773

Basin Total 101.351

Element Flows To:

Surface	Interflow	Groundwater

ANALYSIS RESULTS

Stream Protection Duration

Predeveloped Landuse Totals for POC #1
Total Pervious Area:35.115
Total Impervious Area:0

Mitigated Landuse Totals for POC #1
Total Pervious Area:24.752
Total Impervious Area:10.363

Flow Frequency Return Periods for Predeveloped. POC #1

Return Period	Flow(cfs)
2 year	1.379365
5 year	2.907119
10 year	3.960384
25 year	5.211735
50 year	6.052468
100 year	6.806033

Flow Frequency Return Periods for Mitigated. POC #1

Return Period	Flow(cfs)
2 year	4.881332
5 year	6.774055
10 year	8.185476
25 year	10.157519
50 year	11.769346
100 year	13.508505

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #1

Year	Predeveloped	Mitigated
1949	0.030	4.511
1950	1.153	5.256
1951	1.330	5.147
1952	0.185	4.131
1953	0.175	5.496
1954	3.059	8.171
1955	4.597	7.190
1956	2.574	3.295
1957	3.952	6.421
1958	1.921	10.444
1959	1.272	4.244
1960	1.565	4.509
1961	1.757	12.971
1962	0.857	5.020
1963	0.857	6.193
1964	1.751	4.031
1965	1.680	3.598
1966	0.689	3.680
1967	2.245	8.821
1968	0.474	4.697
1969	0.792	9.339
1970	1.315	3.497
1971	1.914	5.142
1972	2.106	6.269
1973	1.200	5.215
1974	2.335	6.362
1975	1.314	4.998
1976	1.471	3.753
1977	1.405	3.483
1978	1.042	2.806
1979	4.425	8.482
1980	0.444	3.383
1981	1.511	3.479
1982	2.302	3.517
1983	1.628	5.350
1984	1.462	4.951
1985	4.039	6.251
1986	5.118	8.296
1987	1.635	5.119
1988	0.257	4.414
1989	0.394	4.463
1990	0.241	3.511
1991	1.132	4.223
1992	0.591	4.049
1993	0.384	3.559
1994	0.704	3.463
1995	0.564	3.250
1996	5.257	7.797
1997	9.101	11.457
1998	0.145	5.694
1999	1.275	3.212
2000	2.307	8.824
2001	0.134	3.173
2002	1.394	3.172
2003	0.616	4.091
2004	0.581	7.797
2005	1.343	3.654
2006	4.528	7.567
2007	4.038	6.418
2008	3.728	4.561
2009	1.888	3.746

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #1

Rank	Predeveloped	Mitigated
1	9.1006	12.9705
2	5.2566	11.4570

3	5.1175	10.4441
4	4.5966	9.3386
5	4.5282	8.8241
6	4.4254	8.8206
7	4.0385	8.4816
8	4.0380	8.2963
9	3.9521	8.1714
10	3.7276	7.7972
11	3.0588	7.7972
12	2.5740	7.5667
13	2.3351	7.1903
14	2.3068	6.4206
15	2.3017	6.4181
16	2.2453	6.3616
17	2.1057	6.2688
18	1.9207	6.2510
19	1.9139	6.1933
20	1.8880	5.6937
21	1.7574	5.4959
22	1.7509	5.3504
23	1.6797	5.2558
24	1.6345	5.2146
25	1.6276	5.1467
26	1.5645	5.1420
27	1.5107	5.1192
28	1.4712	5.0198
29	1.4621	4.9983
30	1.4051	4.9510
31	1.3938	4.6967
32	1.3427	4.5609
33	1.3302	4.5108
34	1.3153	4.5090
35	1.3140	4.4632
36	1.2749	4.4138
37	1.2716	4.2437
38	1.1995	4.2230
39	1.1526	4.1310
40	1.1323	4.0910
41	1.0424	4.0489
42	0.8571	4.0305
43	0.8570	3.7535
44	0.7916	3.7464
45	0.7036	3.6803
46	0.6890	3.6537
47	0.6161	3.5982
48	0.5914	3.5587
49	0.5805	3.5173
50	0.5639	3.5107
51	0.4743	3.4971
52	0.4440	3.4826
53	0.3935	3.4793
54	0.3838	3.4626
55	0.2568	3.3826
56	0.2414	3.2951
57	0.1847	3.2505
58	0.1753	3.2116
59	0.1448	3.1731
60	0.1344	3.1723
61	0.0296	2.8064

Stream Protection Duration

Predeveloped Landuse Totals for POC #2
Total Pervious Area:101.351
Total Impervious Area:0

Mitigated Landuse Totals for POC #2

Total Pervious Area:88.578
Total Impervious Area:12.773

Flow Frequency Return Periods for Predeveloped. POC #2

Return Period	Flow(cfs)
2 year	3.981204
5 year	8.390699
10 year	11.430695
25 year	15.042419
50 year	17.468994
100 year	19.64398

Flow Frequency Return Periods for Mitigated. POC #2

Return Period	Flow(cfs)
2 year	6.951852
5 year	10.480576
10 year	13.344407
25 year	17.634739
50 year	21.366585
100 year	25.599901

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #2

Year	Predeveloped	Mitigated
1949	0.085	5.568
1950	3.327	6.493
1951	3.839	6.344
1952	0.533	5.095
1953	0.506	6.858
1954	8.829	14.463
1955	13.267	14.317
1956	7.429	6.557
1957	11.407	12.632
1958	5.544	13.449
1959	3.670	6.558
1960	4.516	6.279
1961	5.072	16.003
1962	2.474	6.189
1963	2.473	8.289
1964	5.053	6.347
1965	4.848	5.181
1966	1.988	4.582
1967	6.480	10.873
1968	1.369	5.908
1969	2.285	12.093
1970	3.796	4.318
1971	5.524	8.331
1972	6.078	7.737
1973	3.462	6.504
1974	6.740	7.846
1975	3.792	6.264
1976	4.246	6.651
1977	4.055	4.297
1978	3.009	3.767
1979	12.773	15.739
1980	1.282	4.180
1981	4.360	4.295
1982	6.643	6.274
1983	4.698	7.466
1984	4.220	7.076
1985	11.656	11.146
1986	14.771	16.446
1987	4.718	6.688
1988	0.741	5.797
1989	1.136	5.797
1990	0.697	4.691
1991	3.268	5.208
1992	1.707	4.997
1993	1.108	4.840
1994	2.031	4.275

1995	1.628	4.008
1996	15.172	17.994
1997	26.267	28.691
1998	0.418	7.134
1999	3.680	5.952
2000	6.658	10.904
2001	0.388	3.915
2002	4.023	5.734
2003	1.778	5.044
2004	1.676	9.625
2005	3.875	5.322
2006	13.070	15.753
2007	11.655	12.028
2008	10.759	9.684
2009	5.449	5.351

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #2

Rank	Predeveloped	Mitigated
1	26.2668	28.6905
2	15.1718	17.9943
3	14.7705	16.4460
4	13.2669	16.0029
5	13.0696	15.7527
6	12.7729	15.7387
7	11.6563	14.4631
8	11.6546	14.3174
9	11.4068	13.4486
10	10.7587	12.6321
11	8.8285	12.0930
12	7.4292	12.0284
13	6.7397	11.1460
14	6.6581	10.9040
15	6.6433	10.8730
16	6.4804	9.6838
17	6.0775	9.6252
18	5.5435	8.3308
19	5.5239	8.2888
20	5.4492	7.8463
21	5.0724	7.7374
22	5.0535	7.4657
23	4.8480	7.1343
24	4.7176	7.0763
25	4.6977	6.8577
26	4.5156	6.6877
27	4.3603	6.6513
28	4.2464	6.5581
29	4.2200	6.5571
30	4.0554	6.5041
31	4.0229	6.4932
32	3.8754	6.3471
33	3.8394	6.3439
34	3.7962	6.2795
35	3.7925	6.2741
36	3.6797	6.2644
37	3.6702	6.1888
38	3.4622	5.9522
39	3.3266	5.9083
40	3.2681	5.7968
41	3.0087	5.7966
42	2.4738	5.7337
43	2.4735	5.5675
44	2.2848	5.3510
45	2.0307	5.3219
46	1.9885	5.2078
47	1.7783	5.1810
48	1.7068	5.0953
49	1.6755	5.0440
50	1.6275	4.9968
51	1.3689	4.8404
52	1.2815	4.6908

53	1.1358	4.5820
54	1.1077	4.3175
55	0.7411	4.2975
56	0.6966	4.2955
57	0.5332	4.2746
58	0.5060	4.1802
59	0.4179	4.0080
60	0.3880	3.9153
61	0.0853	3.7671

Stream Protection Duration

Predeveloped Landuse Totals for POC #3
Total Pervious Area:8.39
Total Impervious Area:0

Mitigated Landuse Totals for POC #3
Total Pervious Area:7.92
Total Impervious Area:0.47

Flow Frequency Return Periods for Predeveloped. POC #3

Return Period	Flow(cfs)
2 year	0.329571
5 year	0.694596
10 year	0.946251
25 year	1.245235
50 year	1.446111
100 year	1.62616

Flow Frequency Return Periods for Mitigated. POC #3

Return Period	Flow(cfs)
2 year	0.404831
5 year	0.697472
10 year	0.949315
25 year	1.343525
50 year	1.698954
100 year	2.113122

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #3

Year	Predeveloped	Mitigated
1949	0.007	0.206
1950	0.275	0.508
1951	0.318	0.458
1952	0.044	0.188
1953	0.042	0.271
1954	0.731	1.138
1955	1.098	1.082
1956	0.615	0.513
1957	0.944	0.973
1958	0.459	0.688
1959	0.304	0.502
1960	0.374	0.381
1961	0.420	0.592
1962	0.205	0.303
1963	0.205	0.430
1964	0.418	0.447
1965	0.401	0.380
1966	0.165	0.202
1967	0.536	0.533
1968	0.113	0.321
1969	0.189	0.569
1970	0.314	0.245
1971	0.457	0.621
1972	0.503	0.486
1973	0.287	0.252

1974	0.558	0.504
1975	0.314	0.345
1976	0.352	0.529
1977	0.336	0.192
1978	0.249	0.192
1979	1.057	1.225
1980	0.106	0.197
1981	0.361	0.230
1982	0.550	0.478
1983	0.389	0.440
1984	0.349	0.396
1985	0.965	0.834
1986	1.223	1.243
1987	0.391	0.510
1988	0.061	0.286
1989	0.094	0.273
1990	0.058	0.237
1991	0.271	0.393
1992	0.141	0.185
1993	0.092	0.270
1994	0.168	0.158
1995	0.135	0.221
1996	1.256	1.466
1997	2.174	2.303
1998	0.035	0.285
1999	0.305	0.450
2000	0.551	0.684
2001	0.032	0.144
2002	0.333	0.422
2003	0.147	0.186
2004	0.139	0.356
2005	0.321	0.371
2006	1.082	1.217
2007	0.965	0.887
2008	0.891	0.732
2009	0.451	0.382

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #3

Rank	Predeveloped	Mitigated
1	2.1744	2.3032
2	1.2559	1.4662
3	1.2227	1.2426
4	1.0983	1.2249
5	1.0819	1.2174
6	1.0574	1.1385
7	0.9649	1.0819
8	0.9648	0.9734
9	0.9443	0.8871
10	0.8906	0.8337
11	0.7308	0.7323
12	0.6150	0.6879
13	0.5579	0.6841
14	0.5512	0.6213
15	0.5499	0.5919
16	0.5365	0.5694
17	0.5031	0.5333
18	0.4589	0.5288
19	0.4573	0.5133
20	0.4511	0.5099
21	0.4199	0.5082
22	0.4183	0.5041
23	0.4013	0.5024
24	0.3905	0.4865
25	0.3889	0.4777
26	0.3738	0.4581
27	0.3609	0.4502
28	0.3515	0.4473
29	0.3493	0.4401
30	0.3357	0.4300
31	0.3330	0.4225

32	0.3208	0.3959
33	0.3178	0.3929
34	0.3143	0.3816
35	0.3139	0.3810
36	0.3046	0.3800
37	0.3038	0.3713
38	0.2866	0.3564
39	0.2754	0.3451
40	0.2705	0.3208
41	0.2491	0.3029
42	0.2048	0.2862
43	0.2048	0.2854
44	0.1891	0.2733
45	0.1681	0.2713
46	0.1646	0.2699
47	0.1472	0.2518
48	0.1413	0.2446
49	0.1387	0.2374
50	0.1347	0.2305
51	0.1133	0.2207
52	0.1061	0.2059
53	0.0940	0.2020
54	0.0917	0.1973
55	0.0613	0.1920
56	0.0577	0.1916
57	0.0441	0.1879
58	0.0419	0.1857
59	0.0346	0.1855
60	0.0321	0.1578
61	0.0071	0.1444

Stream Protection Duration

Predeveloped Landuse Totals for POC #4
Total Pervious Area:26.73
Total Impervious Area:0

Mitigated Landuse Totals for POC #4
Total Pervious Area:16.83
Total Impervious Area:9.89

Flow Frequency Return Periods for Predeveloped. POC #4

Return Period	Flow(cfs)
2 year	1.049991
5 year	2.212937
10 year	3.014695
25 year	3.96724
50 year	4.607217
100 year	5.180841

Flow Frequency Return Periods for Mitigated. POC #4

Return Period	Flow(cfs)
2 year	4.539243
5 year	6.215983
10 year	7.428117
25 year	9.079121
50 year	10.398022
100 year	11.795085

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #4

Year	Predeveloped	Mitigated
1949	0.023	4.304
1950	0.877	5.014
1951	1.013	4.912
1952	0.141	3.942

1953	0.133	5.223
1954	2.328	7.137
1955	3.499	6.209
1956	1.959	2.809
1957	3.008	5.446
1958	1.462	9.828
1959	0.968	4.011
1960	1.191	4.127
1961	1.338	12.375
1962	0.652	4.790
1963	0.652	5.761
1964	1.333	3.582
1965	1.279	3.433
1966	0.524	3.498
1967	1.709	8.418
1968	0.361	4.481
1969	0.603	8.766
1970	1.001	3.336
1971	1.457	4.699
1972	1.603	5.981
1973	0.913	4.961
1974	1.778	6.071
1975	1.000	4.747
1976	1.120	3.276
1977	1.070	3.323
1978	0.794	2.614
1979	3.369	7.255
1980	0.338	3.226
1981	1.150	3.319
1982	1.752	3.357
1983	1.239	4.909
1984	1.113	4.554
1985	3.074	5.965
1986	3.896	7.196
1987	1.244	4.884
1988	0.195	4.126
1989	0.300	4.201
1990	0.184	3.272
1991	0.862	4.030
1992	0.450	3.862
1993	0.292	3.288
1994	0.536	3.304
1995	0.429	3.102
1996	4.001	6.329
1997	6.928	9.152
1998	0.110	5.413
1999	0.970	2.761
2000	1.756	8.414
2001	0.102	3.028
2002	1.061	2.905
2003	0.469	3.904
2004	0.442	7.438
2005	1.022	3.486
2006	3.447	6.348
2007	3.074	5.551
2008	2.837	3.828
2009	1.437	3.566

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #4

Rank	**Predeveloped**	**Mitigated**
1	6.9275	12.3749
2	4.0014	9.8276
3	3.8955	9.1518
4	3.4990	8.7665
5	3.4469	8.4179
6	3.3687	8.4144
7	3.0742	7.4385
8	3.0738	7.2545
9	3.0084	7.1964
10	2.8375	7.1366

11	2.3284	6.3475
12	1.9594	6.3294
13	1.7775	6.2091
14	1.7560	6.0706
15	1.7521	5.9809
16	1.7091	5.9647
17	1.6029	5.7615
18	1.4620	5.5514
19	1.4569	5.4456
20	1.4372	5.4129
21	1.3378	5.2230
22	1.3328	5.0139
23	1.2786	4.9613
24	1.2442	4.9118
25	1.2390	4.9087
26	1.1909	4.8839
27	1.1500	4.7905
28	1.1199	4.7465
29	1.1130	4.6986
30	1.0696	4.5537
31	1.0610	4.4812
32	1.0221	4.3036
33	1.0126	4.2007
34	1.0012	4.1267
35	1.0002	4.1263
36	0.9705	4.0299
37	0.9680	4.0107
38	0.9131	3.9419
39	0.8773	3.9041
40	0.8619	3.8622
41	0.7935	3.8276
42	0.6524	3.5821
43	0.6523	3.5656
44	0.6026	3.4975
45	0.5356	3.4864
46	0.5244	3.4330
47	0.4690	3.3565
48	0.4502	3.3363
49	0.4419	3.3230
50	0.4292	3.3193
51	0.3610	3.3038
52	0.3380	3.2878
53	0.2995	3.2759
54	0.2921	3.2722
55	0.1954	3.2264
56	0.1837	3.1019
57	0.1406	3.0278
58	0.1334	2.9045
59	0.1102	2.8086
60	0.1023	2.7606
61	0.0225	2.6136

Stream Protection Duration

Predeveloped Landuse Totals for POC #5
Total Pervious Area:9.59
Total Impervious Area:0

Mitigated Landuse Totals for POC #5
Total Pervious Area:8
Total Impervious Area:1.6

Flow Frequency Return Periods for Predeveloped. POC #5

Return Period	Flow(cfs)
2 year	0.376708
5 year	0.793942

10 year	1.081592
25 year	1.42334
50 year	1.652946
100 year	1.858747

Flow Frequency Return Periods for Mitigated. POC #5

Return Period	Flow(cfs)
2 year	0.908061
5 year	1.336182
10 year	1.66314
25 year	2.128281
50 year	2.514247
100 year	2.935485

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #5

Year	Predeveloped	Mitigated
1949	0.008	0.698
1950	0.315	0.932
1951	0.363	0.834
1952	0.050	0.638
1953	0.048	0.876
1954	0.835	2.015
1955	1.255	1.667
1956	0.703	0.816
1957	1.079	1.555
1958	0.525	1.779
1959	0.347	0.963
1960	0.427	0.907
1961	0.480	2.007
1962	0.234	0.775
1963	0.234	1.128
1964	0.478	0.899
1965	0.459	0.666
1966	0.188	0.588
1967	0.613	1.362
1968	0.130	0.819
1969	0.216	1.618
1970	0.359	0.568
1971	0.523	1.204
1972	0.575	0.970
1973	0.328	0.822
1974	0.638	0.990
1975	0.359	0.799
1976	0.402	0.935
1977	0.384	0.538
1978	0.285	0.505
1979	1.209	2.072
1980	0.121	0.524
1981	0.413	0.561
1982	0.629	0.766
1983	0.445	1.054
1984	0.399	0.933
1985	1.103	1.374
1986	1.398	2.003
1987	0.446	0.859
1988	0.070	0.784
1989	0.107	0.752
1990	0.066	0.630
1991	0.309	0.668
1992	0.162	0.628
1993	0.105	0.678
1994	0.192	0.535
1995	0.154	0.502
1996	1.436	2.033
1997	2.485	2.952
1998	0.040	0.911
1999	0.348	0.762
2000	0.630	1.371
2001	0.037	0.490
2002	0.381	0.733

2003	0.168	0.632
2004	0.159	1.207
2005	0.367	0.677
2006	1.237	1.850
2007	1.103	1.576
2008	1.018	1.083
2009	0.516	0.653

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #5

Rank	Predeveloped	Mitigated
1	2.4854	2.9520
2	1.4356	2.0721
3	1.3976	2.0333
4	1.2553	2.0155
5	1.2367	2.0067
6	1.2086	2.0030
7	1.1029	1.8501
8	1.1028	1.7787
9	1.0793	1.6671
10	1.0180	1.6177
11	0.8354	1.5757
12	0.7030	1.5549
13	0.6377	1.3741
14	0.6300	1.3707
15	0.6286	1.3619
16	0.6132	1.2068
17	0.5751	1.2043
18	0.5245	1.1283
19	0.5227	1.0826
20	0.5156	1.0535
21	0.4800	0.9900
22	0.4782	0.9695
23	0.4587	0.9627
24	0.4464	0.9348
25	0.4445	0.9334
26	0.4273	0.9322
27	0.4126	0.9113
28	0.4018	0.9069
29	0.3993	0.8993
30	0.3837	0.8756
31	0.3807	0.8593
32	0.3667	0.8338
33	0.3633	0.8215
34	0.3592	0.8187
35	0.3588	0.8163
36	0.3482	0.7990
37	0.3473	0.7836
38	0.3276	0.7752
39	0.3148	0.7659
40	0.3092	0.7621
41	0.2847	0.7520
42	0.2341	0.7333
43	0.2340	0.6978
44	0.2162	0.6775
45	0.1922	0.6770
46	0.1882	0.6682
47	0.1683	0.6658
48	0.1615	0.6528
49	0.1585	0.6383
50	0.1540	0.6317
51	0.1295	0.6297
52	0.1213	0.6275
53	0.1075	0.5879
54	0.1048	0.5682
55	0.0701	0.5606
56	0.0659	0.5381
57	0.0505	0.5351
58	0.0479	0.5243
59	0.0395	0.5049
60	0.0367	0.5020

61	0.0081	0.4903

Stream Protection Duration

Predeveloped Landuse Totals for POC #6
Total Pervious Area:52.35
Total Impervious Area:0

Mitigated Landuse Totals for POC #6
Total Pervious Area:45.7
Total Impervious Area:6.65

Flow Frequency Return Periods for Predeveloped. POC #6

Return Period	Flow(cfs)
2 year	2.056379
5 year	4.333979
10 year	5.904203
25 year	7.769737
50 year	9.023116
100 year	10.146543

Flow Frequency Return Periods for Mitigated. POC #6

Return Period	Flow(cfs)
2 year	3.534952
5 year	5.304403
10 year	6.73527
25 year	8.872481
50 year	10.726576
100 year	12.825363

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #6

Year	Predeveloped	Mitigated
1949	0.044	2.898
1950	1.718	3.377
1951	1.983	3.303
1952	0.275	2.652
1953	0.261	3.546
1954	4.560	7.007
1955	6.853	7.217
1956	3.837	3.273
1957	5.892	6.291
1958	2.863	6.858
1959	1.896	3.148
1960	2.332	3.086
1961	2.620	8.328
1962	1.278	3.222
1963	1.278	4.171
1964	2.610	3.095
1965	2.504	2.635
1966	1.027	2.367
1967	3.347	5.661
1968	0.707	3.018
1969	1.180	6.141
1970	1.961	2.247
1971	2.853	4.069
1972	3.139	4.027
1973	1.788	3.373
1974	3.481	4.085
1975	1.959	3.238
1976	2.193	3.213
1977	2.095	2.237
1978	1.554	1.904
1979	6.597	7.727
1980	0.662	2.176
1981	2.252	2.236

1982	3.431	3.133
1983	2.426	3.696
1984	2.180	3.566
1985	6.021	5.578
1986	7.629	8.276
1987	2.437	3.309
1988	0.383	2.930
1989	0.587	2.969
1990	0.360	2.371
1991	1.688	2.711
1992	0.882	2.599
1993	0.572	2.410
1994	1.049	2.225
1995	0.841	2.087
1996	7.837	9.054
1997	13.567	14.681
1998	0.216	3.699
1999	1.901	2.947
2000	3.439	5.670
2001	0.200	2.038
2002	2.078	2.846
2003	0.919	2.626
2004	0.865	5.009
2005	2.002	2.657
2006	6.751	7.919
2007	6.020	6.056
2008	5.557	4.916
2009	2.815	2.688

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #6

Rank	**Predeveloped**	**Mitigated**
1	13.5674	14.6814
2	7.8365	9.0544
3	7.6293	8.3281
4	6.8527	8.2760
5	6.7507	7.9190
6	6.5975	7.7270
7	6.0207	7.2172
8	6.0199	7.0070
9	5.8919	6.8575
10	5.5571	6.2913
11	4.5601	6.1415
12	3.8373	6.0564
13	3.4812	5.6696
14	3.4391	5.6608
15	3.4314	5.5785
16	3.3473	5.0090
17	3.1392	4.9159
18	2.8634	4.1705
19	2.8532	4.0848
20	2.8146	4.0686
21	2.6200	4.0272
22	2.6102	3.6994
23	2.5041	3.6957
24	2.4367	3.5661
25	2.4265	3.5460
26	2.3324	3.3770
27	2.2522	3.3734
28	2.1934	3.3089
29	2.1797	3.3028
30	2.0947	3.2732
31	2.0779	3.2384
32	2.0017	3.2220
33	1.9831	3.2131
34	1.9608	3.1478
35	1.9589	3.1332
36	1.9007	3.0950
37	1.8957	3.0859
38	1.7883	3.0179
39	1.7183	2.9690

40	1.6880	2.9467
41	1.5541	2.9296
42	1.2778	2.8977
43	1.2776	2.8460
44	1.1802	2.7113
45	1.0489	2.6880
46	1.0271	2.6569
47	0.9185	2.6525
48	0.8816	2.6348
49	0.8655	2.6260
50	0.8407	2.5993
51	0.7070	2.4097
52	0.6619	2.3706
53	0.5866	2.3669
54	0.5721	2.2470
55	0.3828	2.2373
56	0.3598	2.2356
57	0.2754	2.2255
58	0.2614	2.1762
59	0.2158	2.0867
60	0.2004	2.0383
61	0.0441	1.9036

Stream Protection Duration

Predeveloped Landuse Totals for POC #7
Total Pervious Area:21
Total Impervious Area:0

Mitigated Landuse Totals for POC #7
Total Pervious Area:19.98
Total Impervious Area:1.02

Flow Frequency Return Periods for Predeveloped. POC #7

Return Period	Flow(cfs)
2 year	0.824908
5 year	1.738559
10 year	2.368448
25 year	3.116799
50 year	3.619587
100 year	4.070246

Flow Frequency Return Periods for Mitigated. POC #7

Return Period	Flow(cfs)
2 year	0.862225
5 year	1.519848
10 year	2.095603
25 year	3.009413
50 year	3.843268
100 year	4.824191

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #7

Year	Predeveloped	Mitigated
1949	0.018	0.447
1950	0.689	1.023
1951	0.796	0.946
1952	0.110	0.408
1953	0.105	0.576
1954	1.829	2.343
1955	2.749	2.484
1956	1.539	1.155
1957	2.363	2.166
1958	1.149	1.390
1959	0.760	0.992
1960	0.936	0.819

1961	1.051	1.283
1962	0.513	0.585
1963	0.513	0.868
1964	1.047	0.899
1965	1.005	0.890
1966	0.412	0.420
1967	1.343	1.184
1968	0.284	0.639
1969	0.473	1.160
1970	0.787	0.472
1971	1.145	1.289
1972	1.259	1.082
1973	0.717	0.542
1974	1.396	1.102
1975	0.786	0.755
1976	0.880	1.083
1977	0.840	0.384
1978	0.623	0.393
1979	2.647	2.616
1980	0.266	0.390
1981	0.903	0.481
1982	1.377	1.073
1983	0.973	0.869
1984	0.874	0.829
1985	2.415	1.867
1986	3.060	2.838
1987	0.977	1.108
1988	0.154	0.579
1989	0.235	0.569
1990	0.144	0.485
1991	0.677	0.834
1992	0.354	0.401
1993	0.230	0.534
1994	0.421	0.343
1995	0.337	0.471
1996	3.144	3.410
1997	5.443	5.594
1998	0.087	0.605
1999	0.762	0.978
2000	1.380	1.486
2001	0.080	0.314
2002	0.834	0.917
2003	0.368	0.403
2004	0.347	0.773
2005	0.803	0.808
2006	2.708	2.788
2007	2.415	2.017
2008	2.229	1.718
2009	1.129	0.854

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #7

Rank	**Predeveloped**	**Mitigated**
1	5.4425	5.5944
2	3.1436	3.4097
3	3.0605	2.8382
4	2.7489	2.7880
5	2.7080	2.6162
6	2.6466	2.4842
7	2.4152	2.3427
8	2.4148	2.1658
9	2.3635	2.0174
10	2.2292	1.8674
11	1.8293	1.7178
12	1.5393	1.4857
13	1.3965	1.3897
14	1.3796	1.2891
15	1.3765	1.2829
16	1.3428	1.1840
17	1.2593	1.1600
18	1.1486	1.1551

19	1.1446	1.1082
20	1.1291	1.1019
21	1.0510	1.0826
22	1.0471	1.0818
23	1.0045	1.0734
24	0.9775	1.0231
25	0.9734	0.9919
26	0.9356	0.9778
27	0.9034	0.9455
28	0.8799	0.9175
29	0.8744	0.8994
30	0.8403	0.8902
31	0.8335	0.8694
32	0.8030	0.8679
33	0.7955	0.8536
34	0.7866	0.8344
35	0.7858	0.8294
36	0.7624	0.8186
37	0.7605	0.8081
38	0.7174	0.7728
39	0.6893	0.7549
40	0.6771	0.6387
41	0.6234	0.6050
42	0.5126	0.5852
43	0.5125	0.5791
44	0.4734	0.5764
45	0.4208	0.5691
46	0.4120	0.5417
47	0.3685	0.5336
48	0.3537	0.4851
49	0.3472	0.4807
50	0.3372	0.4719
51	0.2836	0.4710
52	0.2655	0.4467
53	0.2353	0.4201
54	0.2295	0.4078
55	0.1535	0.4031
56	0.1443	0.4014
57	0.1105	0.3932
58	0.1048	0.3898
59	0.0866	0.3836
60	0.0804	0.3428
61	0.0177	0.3136

Stream Protection Duration

Predeveloped Landuse Totals for POC #8
Total Pervious Area:4.89
Total Impervious Area:0

Mitigated Landuse Totals for POC #8
Total Pervious Area:3.17
Total Impervious Area:1.72

Flow Frequency Return Periods for Predeveloped. POC #8

Return Period	Flow(cfs)
2 year	0.192086
5 year	0.404836
10 year	0.55151
25 year	0.725769
50 year	0.842847
100 year	0.947786

Flow Frequency Return Periods for Mitigated. POC #8

Return Period	Flow(cfs)
2 year	0.838434
5 year	1.160877

10 year	1.395952
25 year	1.718282
50 year	1.977283
100 year	2.252893

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #8

Year	Predeveloped	Mitigated
1949	0.004	0.749
1950	0.161	0.873
1951	0.185	0.854
1952	0.026	0.686
1953	0.024	0.922
1954	0.426	1.512
1955	0.640	1.240
1956	0.358	0.593
1957	0.550	1.106
1958	0.267	1.789
1959	0.177	0.758
1960	0.218	0.819
1961	0.245	2.154
1962	0.119	0.833
1963	0.119	1.082
1964	0.244	0.739
1965	0.234	0.598
1966	0.096	0.619
1967	0.313	1.464
1968	0.066	0.780
1969	0.110	1.610
1970	0.183	0.581
1971	0.267	0.960
1972	0.293	1.041
1973	0.167	0.870
1974	0.325	1.056
1975	0.183	0.838
1976	0.205	0.699
1977	0.196	0.578
1978	0.145	0.486
1979	0.616	1.521
1980	0.062	0.562
1981	0.210	0.578
1982	0.321	0.587
1983	0.227	0.959
1984	0.204	0.857
1985	0.562	1.038
1986	0.713	1.537
1987	0.228	0.850
1988	0.036	0.766
1989	0.055	0.758
1990	0.034	0.609
1991	0.158	0.701
1992	0.082	0.673
1993	0.053	0.633
1994	0.098	0.575
1995	0.079	0.539
1996	0.732	1.276
1997	1.267	1.736
1998	0.020	0.955
1999	0.178	0.565
2000	0.321	1.467
2001	0.019	0.527
2002	0.194	0.555
2003	0.086	0.679
2004	0.081	1.295
2005	0.187	0.606
2006	0.631	1.355
2007	0.562	1.202
2008	0.519	0.792
2009	0.263	0.624

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #8

Rank	Predeveloped	Mitigated
1	1.2673	2.1541
2	0.7320	1.7889
3	0.7126	1.7361
4	0.6401	1.6100
5	0.6306	1.5367
6	0.6163	1.5207
7	0.5624	1.5124
8	0.5623	1.4674
9	0.5504	1.4640
10	0.5191	1.3547
11	0.4260	1.2949
12	0.3584	1.2760
13	0.3252	1.2399
14	0.3212	1.2019
15	0.3205	1.1056
16	0.3127	1.0821
17	0.2932	1.0559
18	0.2675	1.0407
19	0.2665	1.0376
20	0.2629	0.9597
21	0.2447	0.9594
22	0.2438	0.9554
23	0.2339	0.9218
24	0.2276	0.8727
25	0.2267	0.8699
26	0.2179	0.8573
27	0.2104	0.8542
28	0.2049	0.8497
29	0.2036	0.8382
30	0.1957	0.8332
31	0.1941	0.8191
32	0.1870	0.7925
33	0.1852	0.7795
34	0.1832	0.7665
35	0.1830	0.7578
36	0.1775	0.7576
37	0.1771	0.7490
38	0.1670	0.7389
39	0.1605	0.7009
40	0.1577	0.6990
41	0.1452	0.6857
42	0.1194	0.6790
43	0.1193	0.6729
44	0.1102	0.6328
45	0.0980	0.6238
46	0.0959	0.6186
47	0.0858	0.6087
48	0.0824	0.6065
49	0.0808	0.5976
50	0.0785	0.5929
51	0.0660	0.5868
52	0.0618	0.5807
53	0.0548	0.5780
54	0.0534	0.5777
55	0.0358	0.5746
56	0.0336	0.5645
57	0.0257	0.5621
58	0.0244	0.5553
59	0.0202	0.5395
60	0.0187	0.5266
61	0.0041	0.4864

Stream Protection Duration

Predeveloped Landuse Totals for POC #9
Total Pervious Area:18.41

Total Impervious Area:0

Mitigated Landuse Totals for POC #9
Total Pervious Area:14.9
Total Impervious Area:3.5

Flow Frequency Return Periods for Predeveloped. POC #9

Return Period	Flow(cfs)
2 year	0.72317
5 year	1.524137
10 year	2.07634
25 year	2.732395
50 year	3.173173
100 year	3.56825

Flow Frequency Return Periods for Mitigated. POC #9

Return Period	Flow(cfs)
2 year	1.734606
5 year	2.480264
10 year	3.049255
25 year	3.859154
50 year	4.532042
100 year	5.267578

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #9

Year	Predeveloped	Mitigated
1949	0.015	1.524
1950	0.604	1.776
1951	0.697	1.738
1952	0.097	1.396
1953	0.092	1.858
1954	1.604	3.097
1955	2.410	2.948
1956	1.349	1.348
1957	2.072	2.619
1958	1.007	3.547
1959	0.667	1.455
1960	0.820	1.547
1961	0.921	4.381
1962	0.449	1.696
1963	0.449	2.121
1964	0.918	1.453
1965	0.881	1.215
1966	0.361	1.242
1967	1.177	2.979
1968	0.249	1.587
1969	0.415	3.172
1970	0.690	1.182
1971	1.003	1.865
1972	1.104	2.118
1973	0.629	1.766
1974	1.224	2.149
1975	0.689	1.693
1976	0.771	1.420
1977	0.737	1.177
1978	0.547	0.965
1979	2.320	3.322
1980	0.233	1.143
1981	0.792	1.176
1982	1.207	1.349
1983	0.853	1.846
1984	0.767	1.746
1985	2.117	2.343
1986	2.683	3.397
1987	0.857	1.730
1988	0.135	1.503
1989	0.206	1.526
1990	0.127	1.205

1991	0.594	1.427
1992	0.310	1.367
1993	0.201	1.219
1994	0.369	1.170
1995	0.296	1.098
1996	2.756	3.496
1997	4.771	5.462
1998	0.076	1.932
1999	0.668	1.265
2000	1.209	2.981
2001	0.070	1.072
2002	0.731	1.236
2003	0.323	1.382
2004	0.304	2.634
2005	0.704	1.234
2006	2.374	3.204
2007	2.117	2.527
2008	1.954	1.967
2009	0.990	1.270

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #9

Rank	**Predeveloped**	**Mitigated**
1	4.7713	5.4620
2	2.7559	4.3814
3	2.6830	3.5474
4	2.4099	3.4964
5	2.3740	3.3975
6	2.3202	3.3224
7	2.1173	3.2037
8	2.1170	3.1715
9	2.0720	3.0971
10	1.9543	2.9811
11	1.6037	2.9792
12	1.3495	2.9482
13	1.2242	2.6344
14	1.2094	2.6194
15	1.2067	2.5273
16	1.1771	2.3431
17	1.1040	2.1491
18	1.0070	2.1206
19	1.0034	2.1181
20	0.9898	1.9670
21	0.9214	1.9316
22	0.9179	1.8652
23	0.8806	1.8580
24	0.8569	1.8460
25	0.8533	1.7759
26	0.8202	1.7659
27	0.7920	1.7463
28	0.7713	1.7383
29	0.7666	1.7302
30	0.7366	1.6956
31	0.7307	1.6927
32	0.7040	1.5871
33	0.6974	1.5471
34	0.6896	1.5257
35	0.6889	1.5241
36	0.6684	1.5034
37	0.6667	1.4552
38	0.6289	1.4527
39	0.6043	1.4266
40	0.5936	1.4205
41	0.5465	1.3955
42	0.4494	1.3819
43	0.4493	1.3675
44	0.4150	1.3491
45	0.3689	1.3477
46	0.3612	1.2697
47	0.3230	1.2651
48	0.3100	1.2423

49	0.3044	1.2365
50	0.2956	1.2344
51	0.2486	1.2188
52	0.2328	1.2153
53	0.2063	1.2046
54	0.2012	1.1817
55	0.1346	1.1767
56	0.1265	1.1757
57	0.0969	1.1702
58	0.0919	1.1427
59	0.0759	1.0980
60	0.0705	1.0722
61	0.0155	0.9648

Stream Protection Duration

Predeveloped Landuse Totals for POC #10
Total Pervious Area:19.06
Total Impervious Area:0

Mitigated Landuse Totals for POC #10
Total Pervious Area:15
Total Impervious Area:4.07

Flow Frequency Return Periods for Predeveloped. POC #10

Return Period	Flow(cfs)
2 year	0.748703
5 year	1.577949
10 year	2.149649
25 year	2.828867
50 year	3.285207
100 year	3.694233

Flow Frequency Return Periods for Mitigated. POC #10

Return Period	Flow(cfs)
2 year	1.995772
5 year	2.827065
10 year	3.456845
25 year	4.348063
50 year	5.084725
100 year	5.886699

Stream Protection Duration
Annual Peaks for Predeveloped and Mitigated. POC #10

Year	Predeveloped	Mitigated
1949	0.016	1.772
1950	0.626	2.065
1951	0.722	2.021
1952	0.100	1.623
1953	0.095	2.163
1954	1.660	3.543
1955	2.495	3.249
1956	1.397	1.497
1957	2.145	2.917
1958	1.043	4.135
1959	0.690	1.688
1960	0.849	1.813
1961	0.954	5.095
1962	0.465	1.972
1963	0.465	2.473
1964	0.950	1.682
1965	0.912	1.413
1966	0.374	1.447
1967	1.219	3.464
1968	0.257	1.845
1969	0.430	3.701

1970	0.714	1.374
1971	1.039	2.161
1972	1.143	2.463
1973	0.651	2.053
1974	1.267	2.499
1975	0.713	1.970
1976	0.799	1.627
1977	0.763	1.368
1978	0.566	1.123
1979	2.402	3.754
1980	0.241	1.329
1981	0.820	1.367
1982	1.249	1.516
1983	0.883	2.156
1984	0.794	2.018
1985	2.192	2.620
1986	2.778	3.752
1987	0.887	2.012
1988	0.139	1.754
1989	0.214	1.773
1990	0.131	1.403
1991	0.615	1.659
1992	0.321	1.590
1993	0.208	1.425
1994	0.382	1.361
1995	0.306	1.277
1996	2.853	3.791
1997	4.940	5.804
1998	0.079	2.245
1999	0.692	1.424
2000	1.252	3.467
2001	0.073	1.247
2002	0.757	1.395
2003	0.334	1.607
2004	0.315	3.063
2005	0.729	1.435
2006	2.458	3.524
2007	2.192	2.803
2008	2.023	2.148
2009	1.025	1.476

Stream Protection Duration
Ranked Annual Peaks for Predeveloped and Mitigated. POC #10

Rank	Predeveloped	Mitigated
1	4.9397	5.8039
2	2.8532	5.0951
3	2.7777	4.1355
4	2.4950	3.7905
5	2.4579	3.7542
6	2.4021	3.7519
7	2.1921	3.7006
8	2.1918	3.5428
9	2.1452	3.5244
10	2.0233	3.4672
11	1.6603	3.4643
12	1.3971	3.2487
13	1.2675	3.0633
14	1.2521	2.9170
15	1.2493	2.8034
16	1.2187	2.6196
17	1.1429	2.4989
18	1.0425	2.4732
19	1.0388	2.4629
20	1.0248	2.2449
21	0.9539	2.1629
22	0.9504	2.1606
23	0.9117	2.1558
24	0.8872	2.1476
25	0.8834	2.0650
26	0.8492	2.0533
27	0.8200	2.0214

28	0.7986	2.0182
29	0.7936	2.0116
30	0.7627	1.9716
31	0.7565	1.9695
32	0.7288	1.8453
33	0.7220	1.8127
34	0.7139	1.7735
35	0.7132	1.7722
36	0.6920	1.7545
37	0.6902	1.6884
38	0.6511	1.6817
39	0.6256	1.6588
40	0.6146	1.6268
41	0.5658	1.6227
42	0.4652	1.6069
43	0.4652	1.5905
44	0.4297	1.5156
45	0.3819	1.4972
46	0.3740	1.4757
47	0.3344	1.4471
48	0.3210	1.4353
49	0.3151	1.4246
50	0.3061	1.4242
51	0.2574	1.4134
52	0.2410	1.4026
53	0.2136	1.3949
54	0.2083	1.3740
55	0.1394	1.3682
56	0.1310	1.3670
57	0.1003	1.3605
58	0.0952	1.3289
59	0.0786	1.2768
60	0.0730	1.2466
61	0.0160	1.1228

Perlnd and Implnd Changes

No changes have been made.

Appendix G.
Summary of SWMM Hydraulic Results

Scenario: One Gravity Outlet

```
[TITLE]
Scenario: One Gravity Outlet
Smith Island Estuary Restoration
Proj. #: 31852A
Interior Drainage Modeling

[OPTIONS]
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
START_DATE           10/01/1948
START_TIME           00:00:00
REPORT_START_DATE    10/01/1948
REPORT_START_TIME    00:00:00
END_DATE             09/30/2009
END_TIME             23:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:15:00
WET_STEP             00:05:00
DRY_STEP             01:00:00
ROUTING_STEP         0:00:30
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         DEPTH
MIN_SLOPE            0

[EVAPORATION]
;;Type       Parameters
;;---------- ----------
CONSTANT     0.0

[OUTFALLS]
;;               Invert     Outfall    Stage/Table      Tide
;;Name           Elev.      Type       Time Series      Gate
;;-------------- ---------- ---------- ---------------- ----
Pond_Gravity_Outfall 97.86      TIMESERIES Tidecont         YES

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                      Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                     Area     Frac.    Infiltration Parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- -----------------------
Pond             96.86    6.64     2.14     TABULAR    Pond                       0        0
WTC              95.375   7.5      3.625    TABULAR    WTC                        0        0

[CONDUITS]
;;               Inlet            Outlet                      Manning    Inlet      Outlet     Init.      Max.
;;Name           Node             Node             Length     N          Offset     Offset     Flow       Flow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert WTC              Pond             270        0.013      2.485      1          0          0
Pond_Outlet      Pond             Pond_Gravity_Outfall 198        0.013      1          0          0          0

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert CIRCULAR     3                0          0          0          1
```

```
Pond_Outlet      CIRCULAR     3                0          0          0          1

[LOSSES]
;;Link           Inlet      Outlet     Average    Flap Gate
;;-------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert 0.5        1          0          YES
Pond_Outlet      0.5        17         0          NO

[INFLOWS]
;;                                                 Param    Units    Scale    Baseline Baseline
;;Node           Parameter        Time Series      Type     Factor   Factor   Value    Pattern
;;-------------- ---------------- ---------------- -------- -------- -------- -------- --------
Pond             FLOW             Pond_inflow      FLOW     1.0      1.0
WTC              FLOW             WTC_inflow       FLOW     1.0      1.0

[CURVES]
;;Name           Type       X-Value    Y-Value
;;-------------- ---------- ---------- ----------
Pond             Storage    0          290933
Pond                        0.64       295539
Pond                        1.64       302773
Pond                        2.64       310083
Pond                        3.64       317419
Pond                        4.64       324806
Pond                        5.64       332168
Pond                        6.64       339426

WTC              Storage    0          0.001
WTC                         0.5        4661
WTC                         1          26923
WTC                         1.5        45345
WTC                         2          65237
WTC                         2.5        83283
WTC                         3          98352
WTC                         3.5        109373
WTC                         4          118870
WTC                         4.5        125933
WTC                         5          132412
WTC                         5.5        139704
WTC                         6          146489
WTC                         6.5        153279
WTC                         7          160015
WTC                         7.5        167102

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
Tidecont         FILE "K:\project\31800\31852A\WaterRes\SWMM\SWMM_tide_repeating_100.txt"

WTC_inflow       FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 3 4 5 7_seep.txt"

Pond_Inflow      FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 1 2_seep.txt"

[REPORT]
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.016)
--------------------------------------------------------------

Scenario: One Gravity Outlet
Smith Island Estuary Restoration
Proj. #: 31852A

*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Water Quality .......... NO
Flow Routing Method ...... DYNWAVE
Starting Date ............ OCT-01-1948 00:00:00
Ending Date .............. SEP-30-2009 23:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec

WARNING 04: minimum elevation drop used for Conduit WTC_to_Pond_Culvert
WARNING 04: minimum elevation drop used for Conduit Pond_Outlet

**************************        Volume         Volume
Flow Routing Continuity        acre-feet       10^6 gal
**************************     ---------      ---------
Dry Weather Inflow .......         0.000          0.000
Wet Weather Inflow .......         0.000          0.000
Groundwater Inflow .......         0.000          0.000
RDII Inflow ..............         0.000          0.000
External Inflow ..........     13784.184       4491.782
External Outflow .........     13774.006       4488.466
Internal Outflow .........         0.000          0.000
Storage Losses ...........         0.000          0.000
Initial Stored Volume ....        19.359          6.308
Final Stored Volume ......        23.684          7.718
Continuity Error (%) .....         0.042


***************************
Time-Step Critical Elements
***************************
Link Pond_Outlet (11.89%)
```

Link WTC_to_Pond_Culvert (1.77%)

****
Highest Flow Instability Indexes
****
All links are stable.

****
Routing Time Step Summary
****

Minimum Time Step	:	0.85 sec
Average Time Step	:	28.87 sec
Maximum Time Step	:	30.00 sec
Percent in Steady State	:	0.00
Average Iterations per Step	:	2.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
Pond_Gravity_Outfall	OUTFALL	6.75	14.68	112.54	829 22:00
Pond	STORAGE	2.80	5.35	102.21	17624 23:36
WTC	STORAGE	4.28	6.83	102.21	17624 23:42

****
Node InFlow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
Pond_Gravity_Outfall	OUTFALL	0.00	15.81	17625 01:16	0.000	4488.132
Pond	STORAGE	13.11	24.00	17623 23:29	2718.693	4495.789

WTC	STORAGE	28.73	28.73	17623	23:29	1772.792	1774.289

****
Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Feet	Min. Depth Below Rim Feet
Pond	STORAGE	2016.95	1.346	1.294
WTC	STORAGE	2023.47	1.347	0.668

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 ft3	Avg Pcnt Full	Maximum Volume 1000 ft3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CFS
Pond	841.771	40	1659.349	79	17624 23:36	15.81
WTC	280.500	38	638.269	85	17624 23:42	14.02

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal

Pond_Gravity_Outfall	12.00	3.74	15.81	4488.132
System	12.00	3.74	15.81	4488.132

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
WTC_to_Pond_Culvert	CONDUIT	14.02	17623 23:53	1.98	10.92	1.00
Pond_Outlet	CONDUIT	15.81	17625 01:16	2.39	10.55	1.00

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	--- Fraction of Time in Flow Class ---- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change
WTC_to_Pond_Culvert	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0008
Pond_Outlet	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.02	0.0016

****
Conduit Surcharge Summary
****

	Hours	Hours

Conduit	--------- Hours Full -------- Both Ends	Upstream	Dnstream	Above Full Normal Flow	Capacity Limited
WTC_to_Pond_Culvert	2016.14	2016.14	2016.27	13078.28	251.92
Pond_Outlet	1863.08	1863.08	1863.76	45179.44	37.34

Analysis begun on: Thu Oct 03 14:27:46 2013
Analysis ended on: Thu Oct 03 14:33:54 2013
Total elapsed time: 00:06:08

Scenario: Two Gravity Outlets

```
[TITLE]
Scenario: Two Gravity Outlets
Smith Island Estuary Restoration
Proj. #: 31852A
Interior Drainage Modeling

[OPTIONS]
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
START_DATE           10/01/1948
START_TIME           00:00:00
REPORT_START_DATE    10/01/1948
REPORT_START_TIME    00:00:00
END_DATE             09/30/2009
END_TIME             23:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:15:00
WET_STEP             00:05:00
DRY_STEP             01:00:00
ROUTING_STEP         0:00:30
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         DEPTH
MIN_SLOPE            0

[EVAPORATION]
;;Type       Parameters
;;---------- ----------
CONSTANT     0.0

[OUTFALLS]
;;               Invert     Outfall    Stage/Table      Tide
;;Name           Elev.      Type       Time Series      Gate
;;-------------- ---------- ---------- ---------------- ----
Pond_Gravity_Outfall 97.86      TIMESERIES Tidecont         YES
WTC_Gravity_Outfall 97.86      TIMESERIES Tidecont         YES

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                      Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                     Area     Frac.    Infiltration Parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- -----------------------
Pond             96.86    6.64     2.14     TABULAR    Pond                       0        0
WTC              95.375   7.5      3.625    TABULAR    WTC                        0        0

[CONDUITS]
;;               Inlet            Outlet                      Manning    Inlet      Outlet     Init.      Max.
;;Name           Node             Node             Length     N          Offset     Offset     Flow       Flow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert WTC              Pond             270        0.013      2.485      1          0          0
Pond_Outlet      Pond             Pond_Gravity_Outfall 198        0.013      1          0          0          0
WTC_Outlet       WTC              WTC_Gravity_Outfall 341        0.013      2.485      0          0          0

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels
```

```
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert CIRCULAR     3                0          0          0          1
Pond_Outlet      CIRCULAR     3                0          0          0          1
WTC_Outlet       CIRCULAR     3                0          0          0          1

[LOSSES]
;;Link           Inlet      Outlet     Average    Flap Gate
;;-------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert 0.5        1          0          YES
Pond_Outlet      0.5        17         0          NO
WTC_Outlet       0.5        17         0          NO

[INFLOWS]
;;                                                 Param    Units    Scale    Baseline Baseline
;;Node           Parameter        Time Series      Type     Factor   Factor   Value    Pattern
;;-------------- ---------------- ---------------- -------- -------- -------- -------- --------
Pond             FLOW             Pond_inflow      FLOW     1.0      1.0
WTC              FLOW             WTC_inflow       FLOW     1.0      1.0

[CURVES]
;;Name           Type       X-Value    Y-Value
;;-------------- ---------- ---------- ----------
Pond             Storage    0          290933
Pond                        0.64       295539
Pond                        1.64       302773
Pond                        2.64       310083
Pond                        3.64       317419
Pond                        4.64       324806
Pond                        5.64       332168
Pond                        6.64       339426

WTC              Storage    0          0.001
WTC                         0.5        4661
WTC                         1          26923
WTC                         1.5        45345
WTC                         2          65237
WTC                         2.5        83283
WTC                         3          98352
WTC                         3.5        109373
WTC                         4          118870
WTC                         4.5        125933
WTC                         5          132412
WTC                         5.5        139704
WTC                         6          146489
WTC                         6.5        153279
WTC                         7          160015
WTC                         7.5        167102

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
Tidecont         FILE "K:\project\31800\31852A\WaterRes\SWMM\SWMM_tide_repeating_100.txt"

WTC_inflow       FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 3 4 5 7_seep.txt"

Pond_Inflow      FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 1 2_seep.txt"

[REPORT]
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.016)
--------------------------------------------------------------

Scenario: Two Gravity Outlets
Smith Island Estuary Restoration
Proj. #: 31852A

*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Water Quality .......... NO
Flow Routing Method ...... DYNWAVE
Starting Date ............ OCT-01-1948 00:00:00
Ending Date .............. SEP-30-2009 23:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec

WARNING 04: minimum elevation drop used for Conduit WTC_to_Pond_Culvert
WARNING 04: minimum elevation drop used for Conduit Pond_Outlet
WARNING 04: minimum elevation drop used for Conduit WTC_Outlet

**************************        Volume         Volume
Flow Routing Continuity        acre-feet      10^6 gal
**************************     ---------      ---------
Dry Weather Inflow .......         0.000          0.000
Wet Weather Inflow .......         0.000          0.000
Groundwater Inflow .......         0.000          0.000
RDII Inflow ..............         0.000          0.000
External Inflow ..........     13784.182       4491.782
External Outflow .........     13782.160       4491.123
Internal Outflow .........         0.000          0.000
Storage Losses ...........         0.000          0.000
Initial Stored Volume ....        19.376          6.314
Final Stored Volume ......        21.390          6.970
Continuity Error (%) .....         0.000


***************************
Time-Step Critical Elements
***************************
```

Link Pond_Outlet (9.11%)

****
Highest Flow Instability Indexes
****
All links are stable.

****
Routing Time Step Summary
****

Minimum Time Step	:	1.17 sec
Average Time Step	:	29.35 sec
Maximum Time Step	:	30.00 sec
Percent in Steady State	:	0.00
Average Iterations per Step	:	2.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
Pond_Gravity_Outfall	OUTFALL	6.83	14.68	112.54	8134 21:59
WTC_Gravity_Outfall	OUTFALL	6.82	14.68	112.54	8134 21:59
Pond	STORAGE	2.57	4.80	101.66	17625 00:00
WTC	STORAGE	3.81	6.28	101.66	17625 00:00

****
Node InFlow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
Pond_Gravity_Outfall	OUTFALL	0.00	13.13	17625 01:37	0.000	2872.539
WTC_Gravity_Outfall	OUTFALL	0.00	12.06	17625 01:16	0.000	1618.250

Pond	STORAGE	13.06	22.55	17623	23:30	2718.686	2877.915
WTC	STORAGE	28.71	28.71	17623	23:29	1772.783	1774.289

****
Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Feet	Min. Depth Below Rim Feet
Pond	STORAGE	393.11	0.795	1.845
WTC	STORAGE	322.44	0.796	1.219

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 ft3	Avg Pcnt Full	Maximum Volume 1000 ft3	Max Pcnt Full	Time of Max Occurrence days	hr:min	Maximum Outflow CFS
Pond	771.103	37	1478.649	71	17625	00:00	13.13
WTC	224.871	30	553.294	74	17625	00:00	21.20

****
Outfall Loading Summary
****

Flow Avg. Max. Total

Outfall Node	Freq. Pcnt.	Avg Flow CFS	Max Flow CFS	Total Volume 10^6 gal
Pond_Gravity_Outfall	9.32	2.83	13.13	2872.539
WTC_Gravity_Outfall	7.36	2.06	12.06	1618.250
System	8.34	4.89	25.15	4490.789

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
WTC_to_Pond_Culvert	CONDUIT	11.13	17623 23:36	1.58	8.67	1.00
Pond_Outlet	CONDUIT	13.13	17625 01:37	2.02	8.76	1.00
WTC_Outlet	CONDUIT	12.06	17625 01:16	1.85	10.56	1.00

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	--- Fraction of Time in Flow Class ---- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change
WTC_to_Pond_Culvert	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0001
Pond_Outlet	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.02	0.0012
WTC_Outlet	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.01	0.0010

****

Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
WTC_to_Pond_Culvert	321.47	321.47	321.49	478.83	18.65
Pond_Outlet	365.10	365.10	365.22	36350.77	8.82
WTC_Outlet	303.94	303.94	304.05	22672.97	7.67

Analysis begun on: Thu Oct 03 14:40:54 2013
Analysis ended on: Thu Oct 03 14:47:42 2013
Total elapsed time: 00:06:48

```
[TITLE]
Scenario: 2cfs Pump
Smith Island Estuary Restoration
Proj. #: 31852A
Interior Drainage Modeling

[OPTIONS]
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
START_DATE           10/01/1948
START_TIME           00:00:00
REPORT_START_DATE    10/01/1948
REPORT_START_TIME    00:00:00
END_DATE             09/30/2009
END_TIME             23:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:15:00
WET_STEP             00:05:00
DRY_STEP             01:00:00
ROUTING_STEP         0:00:30
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         DEPTH
MIN_SLOPE            0

[EVAPORATION]
;;Type       Parameters
;;---------- ----------
CONSTANT     0.0

[OUTFALLS]
;;               Invert     Outfall    Stage/Table      Tide
;;Name           Elev.      Type       Time Series      Gate
;;-------------- ---------- ---------- ---------------- ----
Pond_Gravity_Outfall 97.86      TIMESERIES Tidecont         YES
WTC_Gravity_Outfall 97.86      TIMESERIES Tidecont         YES
Pond_Pump_Outfall 97.86      TIMESERIES Tidecont         YES

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                      Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                     Area     Frac.    Infiltration Parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- -----------------------
Pond             96.86    6.64     2.14     TABULAR    Pond                       0        0
WTC              95.375   7.5      3.625    TABULAR    WTC                        0        0

[CONDUITS]
;;               Inlet            Outlet                      Manning    Inlet      Outlet     Init.      Max.
;;Name           Node             Node             Length     N          Offset     Offset     Flow       Flow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert WTC              Pond             270        0.013      2.485      1          0          0
Pond_Outlet      Pond             Pond_Gravity_Outfall 198        0.013      1          0          0          0
WTC_Outlet       WTC              WTC_Gravity_Outfall 341        0.013      2.485      0          0          0

[PUMPS]
```

```
;;               Inlet            Outlet           Pump             Init.  Startup  Shutoff 
;;Name           Node             Node             Curve            Status Depth    Depth   
;;-------------- ---------------- ---------------- ---------------- ------ -------- --------
Pond_Pump        Pond             Pond_Pump_Outfall 2cfs             ON     2.54     2.14    

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels   
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert CIRCULAR     3                0          0          0          1                    
Pond_Outlet      CIRCULAR     3                0          0          0          1                    
WTC_Outlet       CIRCULAR     3                0          0          0          1                    

[LOSSES]
;;Link           Inlet      Outlet     Average    Flap Gate 
;;-------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert 0.5        1          0          YES       
Pond_Outlet      0.5        17         0          NO        
WTC_Outlet       0.5        17         0          NO        

[INFLOWS]
;;                                                 Param    Units    Scale    Baseline Baseline
;;Node           Parameter        Time Series      Type     Factor   Factor   Value    Pattern
;;-------------- ---------------- ---------------- -------- -------- -------- -------- --------
Pond             FLOW             Pond_inflow      FLOW     1.0      1.0              
WTC              FLOW             WTC_inflow       FLOW     1.0      1.0              

[CURVES]
;;Name           Type       X-Value    Y-Value   
;;-------------- ---------- ---------- ----------
2cfs             Pump2      0          0         
2cfs                        1          2         
2cfs                        2          2         
2cfs                        3          2         
2cfs                        4          2         
2cfs                        5          2         
2cfs                        6          2         
2cfs                        7          2         
2cfs                        8          2         

Pond             Storage    0          290933    
Pond                        0.64       295539    
Pond                        1.64       302773    
Pond                        2.64       310083    
Pond                        3.64       317419    
Pond                        4.64       324806    
Pond                        5.64       332168    
Pond                        6.64       339426    

WTC              Storage    0          0.001     
WTC                         0.5        4661      
WTC                         1          26923     
WTC                         1.5        45345     
WTC                         2          65237     
WTC                         2.5        83283     
WTC                         3          98352     
WTC                         3.5        109373    
WTC                         4          118870    
WTC                         4.5        125933    
WTC                         5          132412    
WTC                         5.5        139704    
WTC                         6          146489    
WTC                         6.5        153279    
WTC                         7          160015    
```

```
WTC                          7.5        167102

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
Tidecont         FILE "K:\project\31800\31852A\WaterRes\SWMM\SWMM_tide_repeating_100.txt"

WTC_inflow       FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 3 4 5 7_seep.txt"

Pond_Inflow      FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 1 2_seep.txt"

[REPORT]
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.016)
--------------------------------------------------------------

Scenario: 2cfs Pump
Smith Island Estuary Restoration
Proj. #: 31852A

*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Water Quality .......... NO
Flow Routing Method ...... DYNWAVE
Starting Date ............ OCT-01-1948 00:00:00
Ending Date .............. SEP-30-2009 23:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec

WARNING 04: minimum elevation drop used for Conduit WTC_to_Pond_Culvert
WARNING 04: minimum elevation drop used for Conduit Pond_Outlet
WARNING 04: minimum elevation drop used for Conduit WTC_Outlet

**************************        Volume         Volume
Flow Routing Continuity        acre-feet       10^6 gal
**************************     ---------      ---------
Dry Weather Inflow .......         0.000          0.000
Wet Weather Inflow .......         0.000          0.000
Groundwater Inflow .......         0.000          0.000
RDII Inflow ..............         0.000          0.000
External Inflow ..........     13784.181       4491.781
External Outflow .........     13778.945       4490.075
Internal Outflow .........         0.000          0.000
Storage Losses ...........         0.000          0.000
Initial Stored Volume ....        19.376          6.314
Final Stored Volume ......        21.390          6.970
Continuity Error (%) .....         0.023


***************************
Time-Step Critical Elements
***************************
```

Link Pond_Outlet (6.17%)

```
*******************************
Highest Flow Instability Indexes
*******************************
All links are stable.


*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     4.73 sec
Average Time Step           :    29.72 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     2.00


******************
Node Depth Summary
******************

--------------------------------------------------------------------
                               Average  Maximum  Maximum  Time of Max
                                 Depth    Depth      HGL   Occurrence
Node                   Type       Feet     Feet     Feet  days hr:min
--------------------------------------------------------------------
Pond_Gravity_Outfall OUTFALL      6.89    14.68   112.54  4116  22:00
WTC_Gravity_Outfall  OUTFALL      6.89    14.68   112.54  4116  22:00
Pond_Pump_Outfall    OUTFALL      6.89    14.68   112.54  4116  22:00
Pond                 STORAGE      2.31     4.05   100.91  17624  17:50
WTC                  STORAGE      3.64     5.54   100.91  17624  17:41


*******************
Node InFlow Summary
*******************

----------------------------------------------------------------------
--------------
                                 Maximum  Maximum
Lateral       Total
                                 Lateral    Total  Time of Max
Inflow      Inflow
                                  Inflow   Inflow   Occurrence
Volume      Volume
  Node                   Type        CFS      CFS  days hr:min    10^6
gal    10^6 gal
----------------------------------------------------------------------
--------------
  Pond_Gravity_Outfall OUTFALL       0.00     9.33  17625  02:00
0.000    1615.507
```

```
  WTC_Gravity_Outfall  OUTFALL       0.00     8.58  17625  02:00
0.000     963.215
  Pond_Pump_Outfall    OUTFALL       0.00     2.00     0  00:00
0.000    1911.019
  Pond                 STORAGE      13.08    24.21  17623  23:30
2718.681    3532.750
  WTC                  STORAGE      28.74    28.74  17623  23:30
1772.776    1774.289


  *********************
  Node Surcharge Summary
  *********************

  Surcharging occurs when water rises above the top of the highest
conduit.
  ---------------------------------------------------------------------
                                               Max. Height   Min. Depth
                                   Hours       Above Crown    Below Rim
  Node                 Type      Surcharged           Feet         Feet
  ---------------------------------------------------------------------
  Pond                 STORAGE        12.65          0.050        2.590
  WTC                  STORAGE        12.81          0.052        1.963


  ********************
  Node Flooding Summary
  ********************

  No nodes were flooded.


  *********************
  Storage Volume Summary
  *********************

  ----------------------------------------------------------------------
---------------
                        Average     Avg       Maximum     Max    Time of
Max    Maximum
                         Volume    Pcnt        Volume    Pcnt
Occurrence    Outflow
  Storage Unit         1000 ft3    Full      1000 ft3    Full    days
hr:min        CFS
  ----------------------------------------------------------------------
---------------
  Pond                  692.739      33      1237.685      59    17624
17:50      11.33
  WTC                   205.244      27       445.236      60    17624
17:41      19.79


  **********************
  Outfall Loading Summary
```

****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
Pond_Gravity_Outfall	6.76	1.93	9.33	1615.507
WTC_Gravity_Outfall	5.57	1.39	8.58	963.215
Pond_Pump_Outfall	6.64	2.00	2.00	1911.019
System	6.32	5.32	19.91	4489.742

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
WTC_to_Pond_Culvert	CONDUIT	13.33	17623 23:39	2.03	10.38	1.00
Pond_Outlet	CONDUIT	9.33	17625 02:00	1.64	6.22	1.00
WTC_Outlet	CONDUIT	8.58	17625 02:00	1.61	7.51	1.00
Pond_Pump	PUMP	2.00	0 00:00		1.00	

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	--- Fraction of Time in Flow Class ---- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change
WTC_to_Pond_Culvert	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0001

```
[TITLE]
Scenario: 4cfs Pump
Smith Island Estuary Restoration
Proj. #: 31852A
Interior Drainage Modeling

[OPTIONS]
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
START_DATE           10/01/1948
START_TIME           00:00:00
REPORT_START_DATE    10/01/1948
REPORT_START_TIME    00:00:00
END_DATE             09/30/2009
END_TIME             23:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:15:00
WET_STEP             00:05:00
DRY_STEP             01:00:00
ROUTING_STEP         0:00:30
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         DEPTH
MIN_SLOPE            0

[EVAPORATION]
;;Type       Parameters
;;---------- ----------
CONSTANT     0.0

[OUTFALLS]
;;               Invert     Outfall    Stage/Table      Tide
;;Name           Elev.      Type       Time Series      Gate
;;-------------- ---------- ---------- ---------------- ----
Pond_Gravity_Outfall 97.86      TIMESERIES Tidecont         YES
WTC_Gravity_Outfall 97.86      TIMESERIES Tidecont         YES
Pond_Pump_Outfall 97.86      TIMESERIES Tidecont         YES

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                        Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                       Area     Frac.    Infiltration Parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- -----------------------
Pond             96.86    6.64     2.14     TABULAR    Pond                         0        0
WTC              95.375   7.5      3.625    TABULAR    WTC                          0        0

[CONDUITS]
;;               Inlet            Outlet                      Manning    Inlet      Outlet     Init.      Max.
;;Name           Node             Node             Length     N          Offset     Offset     Flow       Flow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert WTC              Pond             270        0.013      2.485      1          0          0
Pond_Outlet      Pond             Pond_Gravity_Outfall 198        0.013      1          0          0          0
WTC_Outlet       WTC              WTC_Gravity_Outfall 341        0.013      2.485      0          0          0

[PUMPS]
```

```
;;               Inlet            Outlet           Pump             Init.  Startup  Shutoff 
;;Name           Node             Node             Curve            Status Depth    Depth   
;;-------------- ---------------- ---------------- ---------------- ------ -------- --------
Pond_Pump        Pond             Pond_Pump_Outfall 4cfs             ON     2.54     2.14    

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels   
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert CIRCULAR     3                0          0          0          1                    
Pond_Outlet      CIRCULAR     3                0          0          0          1                    
WTC_Outlet       CIRCULAR     3                0          0          0          1                    

[LOSSES]
;;Link           Inlet      Outlet     Average    Flap Gate 
;;-------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert 0.5        1          0          YES       
Pond_Outlet      0.5        17         0          NO        
WTC_Outlet       0.5        17         0          NO        

[INFLOWS]
;;                                                 Param    Units    Scale    Baseline Baseline
;;Node           Parameter        Time Series      Type     Factor   Factor   Value    Pattern
;;-------------- ---------------- ---------------- -------- -------- -------- -------- --------
Pond             FLOW             Pond_inflow      FLOW     1.0      1.0      
WTC              FLOW             WTC_inflow       FLOW     1.0      1.0      

[CURVES]
;;Name           Type       X-Value    Y-Value   
;;-------------- ---------- ---------- ----------
4cfs             Pump2      0          0         
4cfs                        1          4         
4cfs                        2          4         
4cfs                        3          4         
4cfs                        4          4         
4cfs                        5          4         
4cfs                        6          4         
4cfs                        7          4         
4cfs                        8          4         

Pond             Storage    0          290933    
Pond                        0.64       295539    
Pond                        1.64       302773    
Pond                        2.64       310083    
Pond                        3.64       317419    
Pond                        4.64       324806    
Pond                        5.64       332168    
Pond                        6.64       339426    

WTC              Storage    0          0.001     
WTC                         0.5        4661      
WTC                         1          26923     
WTC                         1.5        45345     
WTC                         2          65237     
WTC                         2.5        83283     
WTC                         3          98352     
WTC                         3.5        109373    
WTC                         4          118870    
WTC                         4.5        125933    
WTC                         5          132412    
WTC                         5.5        139704    
WTC                         6          146489    
WTC                         6.5        153279    
WTC                         7          160015    
```

```
WTC                         7.5        167102

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
Tidecont         FILE "K:\project\31800\31852A\WaterRes\SWMM\SWMM_tide_repeating_100.txt"

WTC_inflow       FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 3 4 5 7_seep.txt"

Pond_Inflow      FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 1 2_seep.txt"

[REPORT]
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.016)
--------------------------------------------------------------


*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Water Quality .......... NO
Flow Routing Method ...... DYNWAVE
Starting Date ............ OCT-01-1948 00:00:00
Ending Date .............. SEP-30-2009 23:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec

WARNING 04: minimum elevation drop used for Conduit WTC_to_Pond_Culvert
WARNING 04: minimum elevation drop used for Conduit Pond_Outlet
WARNING 04: minimum elevation drop used for Conduit WTC_Outlet

**************************        Volume         Volume
Flow Routing Continuity        acre-feet       10^6 gal
**************************     ---------      ---------
Dry Weather Inflow .......         0.000          0.000
Wet Weather Inflow .......         0.000          0.000
Groundwater Inflow .......         0.000          0.000
RDII Inflow ..............         0.000          0.000
External Inflow ..........     13784.182       4491.781
External Outflow .........     13779.474       4490.247
Internal Outflow .........         0.000          0.000
Storage Losses ...........         0.000          0.000
Initial Stored Volume ....        19.376          6.314
Final Stored Volume ......        21.390          6.970
Continuity Error (%) .....         0.020


***************************
Time-Step Critical Elements
***************************
Link Pond_Outlet (6.23%)
```

```
  ********************************
  Highest Flow Instability Indexes
  ********************************
  All links are stable.


  *************************
  Routing Time Step Summary
  *************************
  Minimum Time Step           :    11.96 sec
  Average Time Step           :    29.72 sec
  Maximum Time Step           :    30.00 sec
  Percent in Steady State     :     0.00
  Average Iterations per Step :     2.00


  ******************
  Node Depth Summary
  ******************

  ---------------------------------------------------------------------
                                 Average  Maximum  Maximum  Time of Max
                                   Depth    Depth      HGL   Occurrence
  Node                 Type         Feet     Feet     Feet  days hr:min
  ---------------------------------------------------------------------
  Pond_Gravity_Outfall OUTFALL      6.89    14.68   112.54  8865  22:00
  WTC_Gravity_Outfall  OUTFALL      6.89    14.68   112.54  8865  22:00
  Pond_Pump_Outfall    OUTFALL      6.89    14.68   112.54  8865  22:00
  Pond                 STORAGE      2.32     3.62   100.48  17624  13:32
  WTC                  STORAGE      3.64     5.12   100.49  17624  13:10


  *******************
  Node InFlow Summary
  *******************

  -----------------------------------------------------------------------
--------------
                                  Maximum  Maximum
Lateral       Total
                                  Lateral    Total  Time of Max
Inflow      Inflow
                                   Inflow   Inflow   Occurrence
Volume      Volume
  Node                 Type           CFS      CFS  days hr:min    10^6
gal    10^6 gal
  -----------------------------------------------------------------------
--------------
  Pond_Gravity_Outfall OUTFALL       0.00     6.84  17624  00:41
0.000    1628.433
  WTC_Gravity_Outfall  OUTFALL       0.00     7.18  17624  00:28
0.000     968.495
  Pond_Pump_Outfall    OUTFALL       0.00     4.00     0  00:00
0.000    1892.986
```

Pond	STORAGE	13.05	24.45	17623	23:30	2718.681	3527.455
WTC	STORAGE	28.74	28.74	17623	23:30	1772.776	1774.289

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 ft3	Avg Pcnt Full	Maximum Volume 1000 ft3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CFS
Pond	693.289	33	1100.381	53	17624 13:32	10.84
WTC	205.281	27	387.448	52	17624 13:10	19.12

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
Pond_Gravity_Outfall	6.79	1.94	6.84	1628.433
WTC_Gravity_Outfall	5.59	1.39	7.18	968.495
Pond_Pump_Outfall	3.29	4.00	4.00	1892.986
System	5.22	7.33	17.93	4489.914

```
  *******************
  Link Flow Summary
  *******************

  ----------------------------------------------------------------------------
------
                                 Maximum  Time of Max   Maximum    Max/
Max/
                                  |Flow|   Occurrence  Velocity    Full
Full
  Link                 Type          CFS  days hr:min    ft/sec    Flow
Depth
  ----------------------------------------------------------------------------
------
  WTC_to_Pond_Culvert  CONDUIT     13.89  17623  23:46      2.31   10.82
0.87
  Pond_Outlet          CONDUIT      6.84  17624  00:41      1.52    4.56
0.94
  WTC_Outlet           CONDUIT      7.18  17624  00:28      1.51    6.28
0.94
  Pond_Pump            PUMP         4.00      0  00:00              1.00


  ***************************
  Flow Classification Summary
  ***************************

  ----------------------------------------------------------------------------
------------------
                      Adjusted    --- Fraction of Time in Flow Class ----
Avg.     Avg.
                       /Actual         Up    Down   Sub   Sup   Up    Down
Froude   Flow
  Conduit               Length    Dry  Dry   Dry    Crit  Crit  Crit  Crit
Number   Change
  ----------------------------------------------------------------------------
------------------
  WTC_to_Pond_Culvert     1.00   0.00  0.00  0.00  1.00  0.00  0.00  0.00
0.00   0.0001
  Pond_Outlet             1.00   0.00  0.00  0.00  1.00  0.00  0.00  0.00
0.01   0.0008
  WTC_Outlet              1.00   0.00  0.00  0.00  1.00  0.00  0.00  0.00
0.01   0.0007


  *************************
  Conduit Surcharge Summary
  *************************

  ----------------------------------------------------------------------------
-----
```

```
                                                                  Hours
Hours
                         --------- Hours Full --------   Above Full
Capacity
  Conduit                Both Ends  Upstream  Dnstream   Normal Flow
Limited
  ------------------------------------------------------------------------
-----
  WTC_to_Pond_Culvert         0.01      0.01      0.01   4436.82
0.01
  Pond_Outlet                 0.01      0.01      0.01  25790.54
0.01
  WTC_Outlet                  0.01      0.01      0.01  16484.19
0.01


  ***************
  Pumping Summary
  ***************

  ------------------------------------------------------------------------
---------
                                      Max       Avg        Total
Power  % Time
                        Percent      Flow      Flow       Volume
Usage    Off
  Pump                 Utilized       CFS       CFS      10^6 gal     Kw-
hr   Curve
  ------------------------------------------------------------------------
---------
  Pond_Pump                3.29      4.00      4.00     1892.986
33321.10    0.00


  Analysis begun on:  Tue Oct 01 16:39:59 2013
  Analysis ended on:  Tue Oct 01 16:46:55 2013
  Total elapsed time: 00:06:56
```

Pond_Outlet	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.01 0.0008
WTC_Outlet	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.01 0.0007

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
WTC_to_Pond_Culvert	12.57	12.57	12.57	1366.89	12.37
Pond_Outlet	12.34	12.34	12.35	25420.03	0.02
WTC_Outlet	12.57	12.57	12.58	16295.89	0.03

****
Pumping Summary
****

Pump	Percent Utilized	Max Flow CFS	Avg Flow CFS	Total Volume 10^6 gal	Power Usage Kw-hr	% Time Off Curve
Pond_Pump	6.64	2.00	2.00	1911.019	34646.25	0.00

Analysis begun on: Thu Oct 03 14:58:54 2013
Analysis ended on: Thu Oct 03 15:05:56 2013
Total elapsed time: 00:07:02

```
[TITLE]
Scenario: Two Gravity Outlets - 1996 Flood
Smith Island Estuary Restoration
Proj. #: 31852A
Interior Drainage Modeling

[OPTIONS]
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
START_DATE           10/01/1996
START_TIME           00:00:00
REPORT_START_DATE    12/20/1996
REPORT_START_TIME    00:00:00
END_DATE             01/31/1997
END_TIME             23:45:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:15:00
WET_STEP             00:05:00
DRY_STEP             01:00:00
ROUTING_STEP         0:00:30
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         DEPTH
MIN_SLOPE            0

[EVAPORATION]
;;Type       Parameters
;;---------- ----------
CONSTANT     0.0

[OUTFALLS]
;;               Invert     Outfall    Stage/Table      Tide
;;Name           Elev.      Type       Time Series      Gate
;;-------------- ---------- ---------- ---------------- ----
Pond_Gravity_Outfall 97.86      TIMESERIES Tide_Flood       YES
WTC_Gravity_Outfall 97.86      TIMESERIES Tide_Flood       YES

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                      Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                     Area     Frac.    Infiltration Parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- -----------------------
Pond             96.86    7.14     2.14     TABULAR    Pond                       0        0
WTC              95.375   9.5      3.625    TABULAR    WTC                        0        0

[CONDUITS]
;;               Inlet            Outlet                      Manning    Inlet      Outlet     Init.      Max.
;;Name           Node             Node             Length     N          Offset     Offset     Flow       Flow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert WTC              Pond             270        0.013      2.485      1          0          0
Pond_Outlet      Pond             Pond_Gravity_Outfall 198        0.013      1          0          0          0
WTC_Outlet       WTC              WTC_Gravity_Outfall 341        0.013      2.485      0          0          0

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels
```

```
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert CIRCULAR     3                0          0          0          1
Pond_Outlet      CIRCULAR     3                0          0          0          1
WTC_Outlet       CIRCULAR     3                0          0          0          1

[LOSSES]
;;Link           Inlet      Outlet     Average    Flap Gate
;;-------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert 0.5        1          0          YES
Pond_Outlet      0.5        17         0          NO
WTC_Outlet       0.5        17         0          NO

[INFLOWS]
;;                                                 Param    Units    Scale    Baseline Baseline
;;Node           Parameter        Time Series      Type     Factor   Factor   Value    Pattern
;;-------------- ---------------- ---------------- -------- -------- -------- -------- --------
Pond             FLOW             Pond_inflow      FLOW     1.0      1.0
WTC              FLOW             WTC_inflow       FLOW     1.0      1.0

[CURVES]
;;Name           Type       X-Value    Y-Value
;;-------------- ---------- ---------- ----------
Pond             Storage    0          290933
Pond                        0.64       295539
Pond                        1.64       302773
Pond                        2.64       310083
Pond                        3.64       317419
Pond                        4.64       324806
Pond                        5.64       332168
Pond                        6.64       339426
Pond                        7.14       361652

WTC              Storage    0          0.001
WTC                         0.5        4661
WTC                         1          26923
WTC                         1.5        45345
WTC                         2          65237
WTC                         2.5        83283
WTC                         3          98352
WTC                         3.5        109373
WTC                         4          118870
WTC                         4.5        125933
WTC                         5          132412
WTC                         5.5        139704
WTC                         6          146489
WTC                         6.5        153279
WTC                         7          160015
WTC                         7.5        167102
WTC                         8          180986
WTC                         8.5        195080
WTC                         9          218117
WTC                         9.5        255442

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
WTC_inflow       FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 3 4 5 7_WY1997_seep_flood.txt"

Pond_Inflow      FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins  1 2_WY1997_seep_flood.txt"

Tide_Flood       FILE "K:\project\31800\31852A\WaterRes\SWMM\091613 Models\SWMM_tide_WY1997_96flood.txt"

[REPORT]
```

```
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.016)
--------------------------------------------------------------

Scenario: Two Gravity Outlets - 1996 Flood
Smith Island Estuary Restoration
Project #: 38152A

*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Water Quality .......... NO
Flow Routing Method ...... DYNWAVE
Starting Date ............ OCT-01-1996 00:00:00
Ending Date .............. JAN-31-1997 23:45:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec

WARNING 04: minimum elevation drop used for Conduit WTC_to_Pond_Culvert
WARNING 04: minimum elevation drop used for Conduit Pond_Outlet
WARNING 04: minimum elevation drop used for Conduit WTC_Outlet

**************************        Volume         Volume
Flow Routing Continuity        acre-feet       10^6 gal
**************************     ---------      ---------
Dry Weather Inflow .......         0.000          0.000
Wet Weather Inflow .......         0.000          0.000
Groundwater Inflow .......         0.000          0.000
RDII Inflow ..............         0.000          0.000
External Inflow ..........       149.217         48.625
External Outflow .........       143.807         46.862
Internal Outflow .........         0.000          0.000
Storage Losses ...........         0.000          0.000
Initial Stored Volume ....        19.376          6.314
Final Stored Volume ......        24.839          8.094
Continuity Error (%) .....        -0.031


***************************
Time-Step Critical Elements
***************************
```

Link Pond_Outlet (10.84%)
Link WTC_to_Pond_Culvert (2.01%)

****
Highest Flow Instability Indexes
****
All links are stable.

****
Routing Time Step Summary
****

Minimum Time Step	:	0.69 sec
Average Time Step	:	10.04 sec
Maximum Time Step	:	30.00 sec
Percent in Steady State	:	0.00
Average Iterations per Step	:	0.72

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
Pond_Gravity_Outfall	OUTFALL	2.93	14.68	112.54	99 21:59
WTC_Gravity_Outfall	OUTFALL	2.93	14.68	112.54	99 21:59
Pond	STORAGE	1.32	6.59	103.45	95 01:01
WTC	STORAGE	1.76	8.07	103.45	95 01:01

****
Node InFlow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
Pond_Gravity_Outfall	OUTFALL	0.00	18.82	95 17:00	0.000	27.680

WTC_Gravity_Outfall	OUTFALL	0.00	16.76	95	17:00	0.000	19.178
Pond	STORAGE	11.82	23.17	91	23:30	11.574	33.739
WTC	STORAGE	28.75	28.75	91	23:29	15.868	26.813

****
Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Feet	Min. Depth Below Rim Feet
Pond	STORAGE	344.37	2.588	0.552
WTC	STORAGE	239.91	2.588	1.427

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 ft3	Avg Pcnt Full	Maximum Volume 1000 ft3	Max Pcnt Full	Time of Max Occurrence days	hr:min	Maximum Outflow CFS
Pond	403.601	18	2074.791	91	95	01:01	18.82
WTC	131.115	11	847.045	74	95	01:01	16.76

****
Outfall Loading Summary
****

```
[TITLE]
Scenario: 2cfs Pump - 1996 Flood
Smith Island Estuary Restoration
Proj. #: 31852A
Interior Drainage Modeling

[OPTIONS]
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
START_DATE           10/01/1996
START_TIME           00:00:00
REPORT_START_DATE    12/20/1996
REPORT_START_TIME    00:00:00
END_DATE             01/31/1997
END_TIME             23:45:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:15:00
WET_STEP             00:05:00
DRY_STEP             01:00:00
ROUTING_STEP         0:00:30
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         DEPTH
MIN_SLOPE            0

[EVAPORATION]
;;Type       Parameters
;;---------- ----------
CONSTANT     0.0

[OUTFALLS]
;;               Invert     Outfall    Stage/Table      Tide
;;Name           Elev.      Type       Time Series      Gate
;;-------------- ---------- ---------- ---------------- ----
Pond_Gravity_Outfall 97.86      TIMESERIES Tide_Flood       YES
WTC_Gravity_Outfall 97.86      TIMESERIES Tide_Flood       YES
Pond_Pump_Outfall 97.86      TIMESERIES Tide_Flood       YES

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                      Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                     Area     Frac.    Infiltration Parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- -----------------------
Pond             96.86    7.14     2.14     TABULAR    Pond                       0        0
WTC              95.375   9.5      3.625    TABULAR    WTC                        0        0

[CONDUITS]
;;               Inlet            Outlet                      Manning    Inlet      Outlet     Init.      Max.
;;Name           Node             Node             Length     N          Offset     Offset     Flow       Flow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert WTC              Pond             270        0.013      2.485      1          0          0
Pond_Outlet      Pond             Pond_Gravity_Outfall 198        0.013      1          0          0          0
WTC_Outlet       WTC              WTC_Gravity_Outfall 341        0.013      2.485      0          0          0

[PUMPS]
```

Scenario: 2cfs Pump - 1996 Flood

```
;;               Inlet            Outlet           Pump             Init.  Startup  Shutoff 
;;Name           Node             Node             Curve            Status Depth    Depth   
;;-------------- ---------------- ---------------- ---------------- ------ -------- --------
Pond_Pump        Pond             Pond_Pump_Outfall 2cfs             ON     2.54     2.14    

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels   
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert CIRCULAR     3                0          0          0          1                    
Pond_Outlet      CIRCULAR     3                0          0          0          1                    
WTC_Outlet       CIRCULAR     3                0          0          0          1                    

[LOSSES]
;;Link           Inlet      Outlet     Average    Flap Gate 
;;-------------- ---------- ---------- ---------- ----------
WTC_to_Pond_Culvert 0.5        1          0          YES       
Pond_Outlet      0.5        17         0          NO        
WTC_Outlet       0.5        17         0          NO        

[INFLOWS]
;;                                                 Param    Units    Scale    Baseline Baseline
;;Node           Parameter        Time Series      Type     Factor   Factor   Value    Pattern 
;;-------------- ---------------- ---------------- -------- -------- -------- -------- --------
Pond             FLOW             Pond_inflow      FLOW     1.0      1.0              
WTC              FLOW             WTC_inflow       FLOW     1.0      1.0              

[CURVES]
;;Name           Type       X-Value    Y-Value   
;;-------------- ---------- ---------- ----------
2cfs             Pump2      0          0         
2cfs                        1          2         
2cfs                        2          2         
2cfs                        3          2         
2cfs                        4          2         
2cfs                        5          2         
2cfs                        6          2         
2cfs                        7          2         
2cfs                        8          2         

Pond             Storage    0          290933    
Pond                        0.64       295539    
Pond                        1.64       302773    
Pond                        2.64       310083    
Pond                        3.64       317419    
Pond                        4.64       324806    
Pond                        5.64       332168    
Pond                        6.64       339426    
Pond                        7.14       361652    

WTC              Storage    0          0.001     
WTC                         0.5        4661      
WTC                         1          26923     
WTC                         1.5        45345     
WTC                         2          65237     
WTC                         2.5        83283     
WTC                         3          98352     
WTC                         3.5        109373    
WTC                         4          118870    
WTC                         4.5        125933    
WTC                         5          132412    
WTC                         5.5        139704    
WTC                         6          146489    
WTC                         6.5        153279    
```

```
WTC                         7          160015
WTC                         7.5        167102
WTC                         8          180986
WTC                         8.5        195080
WTC                         9          218117
WTC                         9.5        255442

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
WTC_inflow       FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins 3 4 5 7_WY1997_seep_flood.txt"

Pond_Inflow      FILE "K:\project\31800\31852A\WaterRes\WWHM\Runoff Time Series\Basins  1 2_WY1997_seep_flood.txt"

Tide_Flood       FILE "K:\project\31800\31852A\WaterRes\SWMM\091613 Models\SWMM_tide_WY1997_96flood.txt"

[REPORT]
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.016)
--------------------------------------------------------------

Scenario: 2cfs Pump - 1996 Flood
Smith Island Estuary Restoration
Proj #: 31852A

*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Water Quality .......... NO
Flow Routing Method ...... DYNWAVE
Starting Date ............ OCT-01-1996 00:00:00
Ending Date .............. JAN-31-1997 23:45:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec

WARNING 04: minimum elevation drop used for Conduit WTC_to_Pond_Culvert
WARNING 04: minimum elevation drop used for Conduit Pond_Outlet
WARNING 04: minimum elevation drop used for Conduit WTC_Outlet

**************************        Volume         Volume
Flow Routing Continuity        acre-feet       10^6 gal
**************************     ---------      ---------
Dry Weather Inflow .......         0.000          0.000
Wet Weather Inflow .......         0.000          0.000
Groundwater Inflow .......         0.000          0.000
RDII Inflow ..............         0.000          0.000
External Inflow ..........       149.217         48.624
External Outflow .........       145.915         47.548
Internal Outflow .........         0.000          0.000
Storage Losses ...........         0.000          0.000
Initial Stored Volume ....        19.376          6.314
Final Stored Volume ......        22.694          7.395
Continuity Error (%) .....        -0.009


***************************
Time-Step Critical Elements
***************************
```

```
  Link Pond_Outlet (5.76%)
  Link WTC_to_Pond_Culvert (2.90%)


  *******************************
  Highest Flow Instability Indexes
  *******************************
  All links are stable.


  *************************
  Routing Time Step Summary
  *************************
  Minimum Time Step           :     1.76 sec
  Average Time Step           :    10.31 sec
  Maximum Time Step           :    30.00 sec
  Percent in Steady State     :     0.00
  Average Iterations per Step :     0.71


  ******************
  Node Depth Summary
  ******************

  ---------------------------------------------------------------------
                               Average  Maximum  Maximum  Time of Max
                                 Depth    Depth      HGL   Occurrence
  Node                 Type       Feet     Feet     Feet  days hr:min
  ---------------------------------------------------------------------
  Pond_Gravity_Outfall OUTFALL       2.99    14.68   112.54    99  21:59
  WTC_Gravity_Outfall  OUTFALL       2.99    14.68   112.54    99  21:59
  Pond_Pump_Outfall    OUTFALL       2.99    14.68   112.54    99  21:59
  Pond                 STORAGE       0.94     4.66   101.52    93  13:09
  WTC                  STORAGE       1.46     6.14   101.52    93  12:59


  *******************
  Node InFlow Summary
  *******************

  -----------------------------------------------------------------------
--------------
                                  Maximum  Maximum
Lateral       Total
                                  Lateral    Total  Time of Max
Inflow      Inflow
                                   Inflow   Inflow   Occurrence
Volume      Volume
  Node                 Type            CFS      CFS  days hr:min    10^6
gal    10^6 gal
  -----------------------------------------------------------------------
--------------
  Pond_Gravity_Outfall OUTFALL        0.00     9.61    95  17:00
0.000       8.871
```

WTC_Gravity_Outfall	OUTFALL	0.00	9.03	95	17:00	0.000	7.406
Pond_Pump_Outfall	OUTFALL	0.00	2.00	80	17:45	0.000	31.268
Pond	STORAGE	11.83	24.42	91	23:29	11.574	45.701
WTC	STORAGE	28.79	28.79	91	23:29	15.868	26.813

****

Node Surcharge Summary

****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Feet	Min. Depth Below Rim Feet
Pond	STORAGE	101.98	0.656	2.484
WTC	STORAGE	102.31	0.657	3.358

****

Node Flooding Summary

****

No nodes were flooded.

****

Storage Volume Summary

****

Storage Unit	Average Volume 1000 ft3	Avg Pcnt Full	Maximum Volume 1000 ft3	Max Pcnt Full	Time of Max Occurrence days	hr:min	Maximum Outflow CFS
Pond	282.225	12	1433.268	63	93	13:09	11.61
WTC	93.177	8	532.646	46	93	12:59	13.43

****

Outfall Loading Summary

****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
Pond_Gravity_Outfall	2.11	3.36	9.61	8.871
WTC_Gravity_Outfall	2.06	3.04	9.03	7.406
Pond_Pump_Outfall	13.83	2.00	2.00	31.268
System	6.00	8.40	20.65	47.545

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
WTC_to_Pond_Culvert	CONDUIT	13.43	91	23:44	1.94	10.46	1.00
Pond_Outlet	CONDUIT	9.61	95	17:00	1.68	6.41	1.00
WTC_Outlet	CONDUIT	9.03	95	17:00	1.60	7.91	1.00
Pond_Pump	PUMP	2.00	80	17:45		1.00	

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	--- Fraction of Time in Flow Class ---- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change
WTC_to_Pond_Culvert	1.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.01	0.0003

```
  Pond_Outlet             1.00   0.00  0.00  0.00  0.35  0.00  0.00  0.00
0.00   0.0003
  WTC_Outlet              1.00   0.00  0.00  0.00  0.35  0.00  0.00  0.00
0.00   0.0003


  *************************
  Conduit Surcharge Summary
  *************************

  ----------------------------------------------------------------------------
-----
                                                           Hours
Hours
                         --------- Hours Full --------   Above Full
Capacity
  Conduit                Both Ends  Upstream  Dnstream   Normal Flow
Limited
  ----------------------------------------------------------------------------
-----
  WTC_to_Pond_Culvert       101.97    101.97    101.98     60.28
57.98
  Pond_Outlet               100.55    100.55    100.57     39.88
0.72
  WTC_Outlet                100.88    100.88    100.89     44.38
0.61


  ***************
  Pumping Summary
  ***************

  ----------------------------------------------------------------------------
---------
                                      Max       Avg        Total
Power  % Time
                        Percent      Flow      Flow       Volume
Usage    Off
  Pump                 Utilized       CFS       CFS     10^6 gal     Kw-
hr   Curve
  ----------------------------------------------------------------------------
---------
  Pond_Pump               13.09      2.00      2.00       20.804
508.08    0.00


  Analysis begun on:  Wed Oct 02 12:56:47 2013
  Analysis ended on:  Wed Oct 02 12:56:50 2013
  Total elapsed time: 00:00:03
```

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
Pond_Gravity_Outfall	5.29	7.19	18.82	27.680
WTC_Gravity_Outfall	4.55	5.69	16.76	19.178
System	4.92	12.88	35.59	46.858

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
WTC_to_Pond_Culvert	CONDUIT	12.15	91 23:44	1.72	9.47	1.00
Pond_Outlet	CONDUIT	18.82	95 17:00	2.70	12.56	1.00
WTC_Outlet	CONDUIT	16.76	95 17:00	2.40	14.68	1.00

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	--- Fraction of Time in Flow Class ---- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change
WTC_to_Pond_Culvert	1.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.0002
Pond_Outlet	1.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.01	0.0009
WTC_Outlet	1.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.01	0.0008

****
Conduit Surcharge Summary
****

Conduit	Hours Full: Both Ends	Hours Full: Upstream	Hours Full: Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
WTC_to_Pond_Culvert	239.77	239.77	239.78	34.89	25.08
Pond_Outlet	330.07	330.07	330.13	93.55	11.88
WTC_Outlet	232.65	232.65	232.69	79.76	7.78

Analysis begun on: Wed Oct 02 12:55:37 2013
Analysis ended on: Wed Oct 02 12:55:39 2013
Total elapsed time: 00:00:02

Appendix H.
Modeled 1% Annual Chance (100-year) Flood Conditions

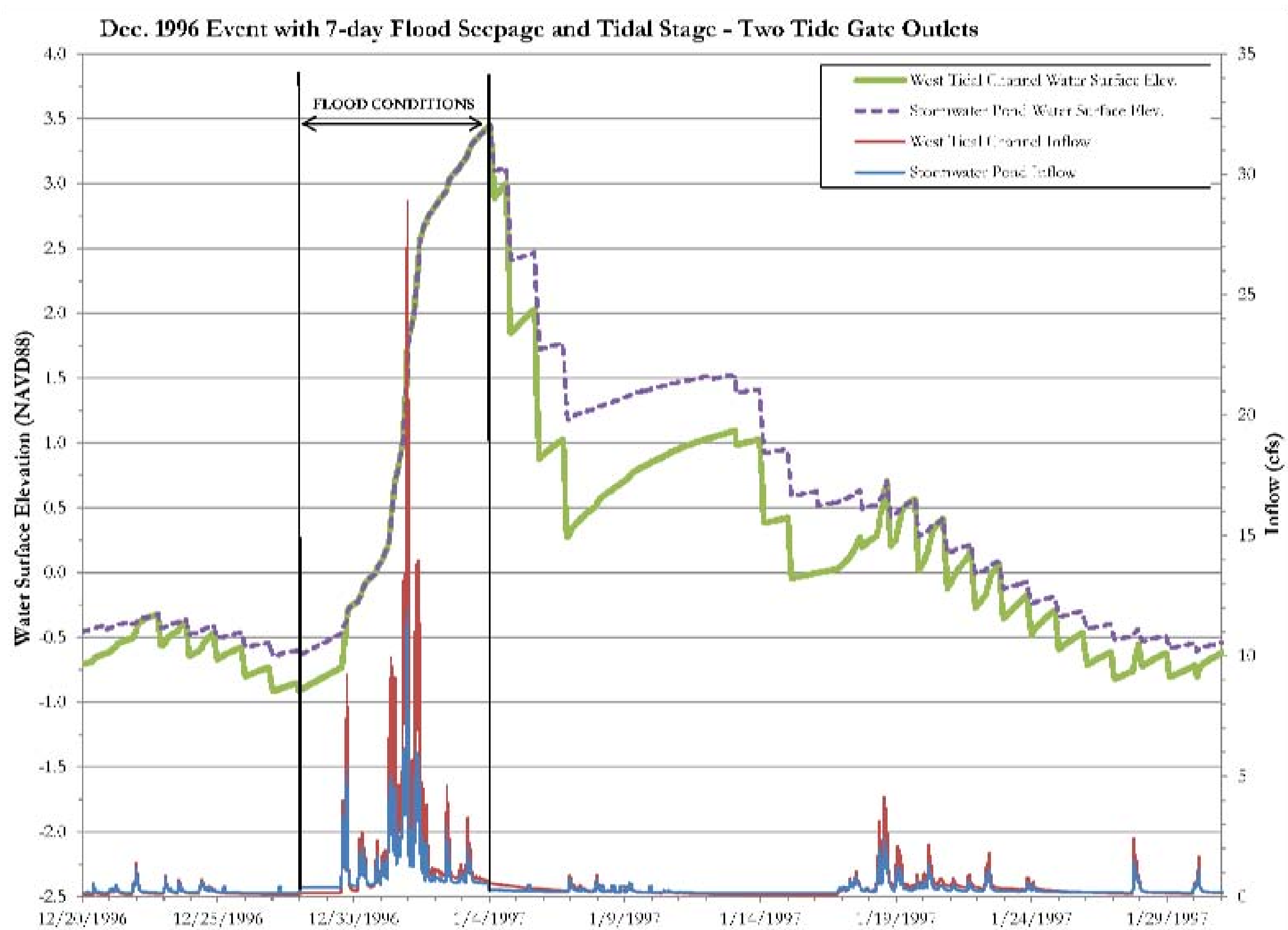


Figure H-1. Modeled stage for the West Tidal Channel and stormwater pond for 7-day flood conditions and two gravity pipe stormwater system.

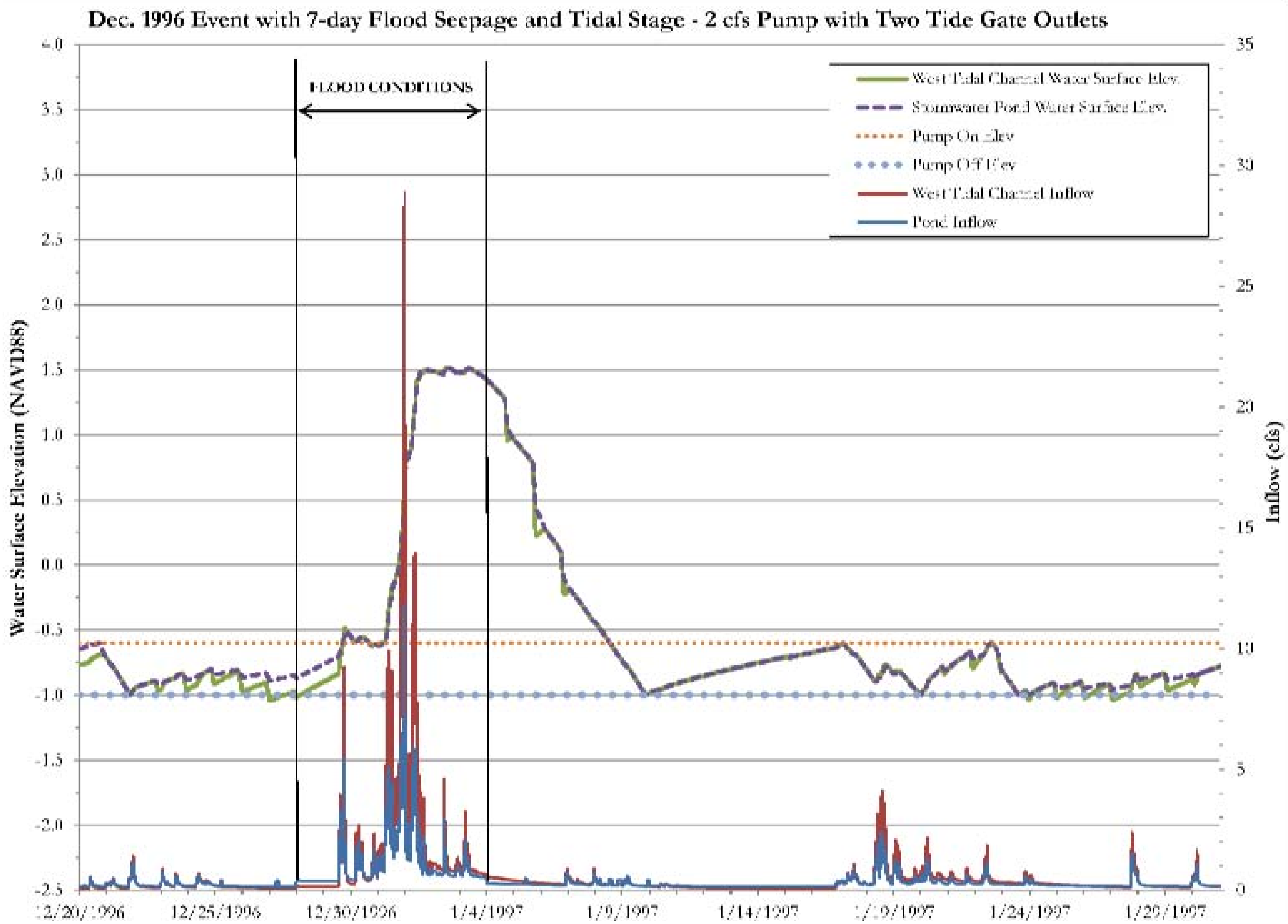


Figure H-2. Modeled stage for the West Tidal Channel and stormwater pond for 7-day flood conditions and a 2cfs pump station with two gravity pipes..

Appendix I.
West Tidal Channel and Stormwater Pond Percent Exceedance

Table I-1. Percent Exceedance of the West Tidal Channel Peak Daily Water Surface Elevation for the Design Alternatives.

West Tidal Channel Peak Daily Water Surface Elevation (NAVD88)	Exceedance Frequency			
	1 Gravity Outlet	2 Gravity Outlets	2 cfs Pump	4 cfs Pump
2.5	0.00%	0.00%	0.00%	0.00%
2.0	0.03%	0.00%	0.00%	0.00%
1.5	0.09%	0.02%	0.00%	0.00%
1.0	0.29%	0.07%	0.00%	0.00%
0.5	2.11%	0.45%	0.03%	0.00%
0.0	14.38%	3.61%	0.06%	0.03%
-0.5	67.82%	22.27%	0.25%	0.13%
-1.0	100.00%	68.15%	62.00%	62.71%
-1.5	100.00%	100.00%	100.00%	100.00%

Table I-2. Percent Exceedance of the Stormwater Pond Peak Daily Water Surface Elevation for the Design Alternatives.

Pond Peak Daily Water Surface Elevation (NAVD88)	Percent Exceedance			
	1 Gravity Outlet	2 Gravity Outlets	2 cfs Pump	4 cfs Pump
2.5	0.00%	0.00%	0.00%	0.00%
2.0	0.03%	0.00%	0.00%	0.00%
1.5	0.09%	0.02%	0.00%	0.00%
1.0	0.29%	0.07%	0.00%	0.00%
0.5	2.11%	0.51%	0.02%	0.00%
0.0	14.44%	4.39%	0.05%	0.02%
-0.5	68.52%	36.53%	0.23%	0.10%
-1.0	100.00%	100.00%	99.69%	99.88%
-1.5	100.00%	100.00%	100.00%	100.00%